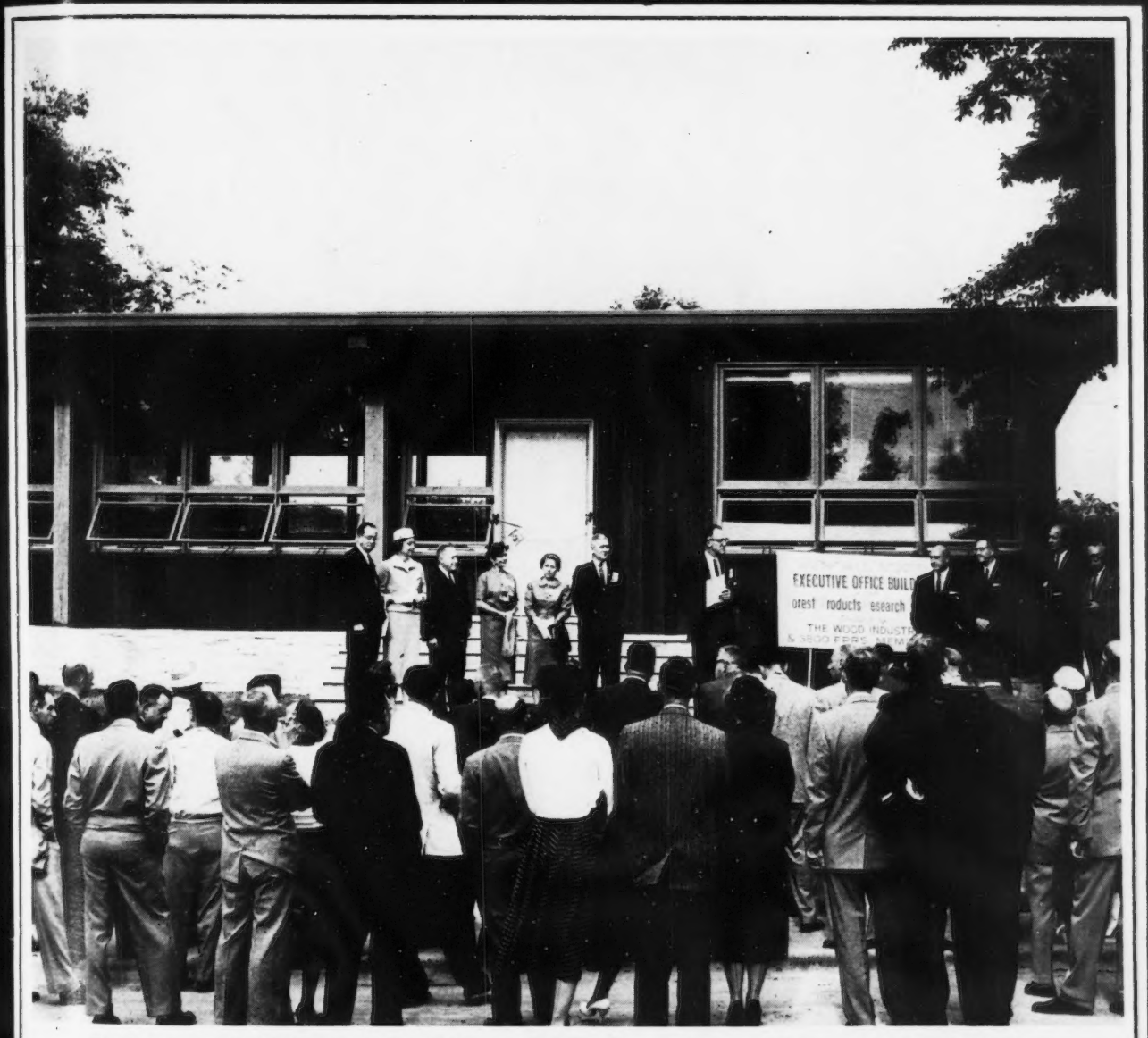
LUMBER—CAN IT COMPETE?—p. 9-A

Forest Products Journal



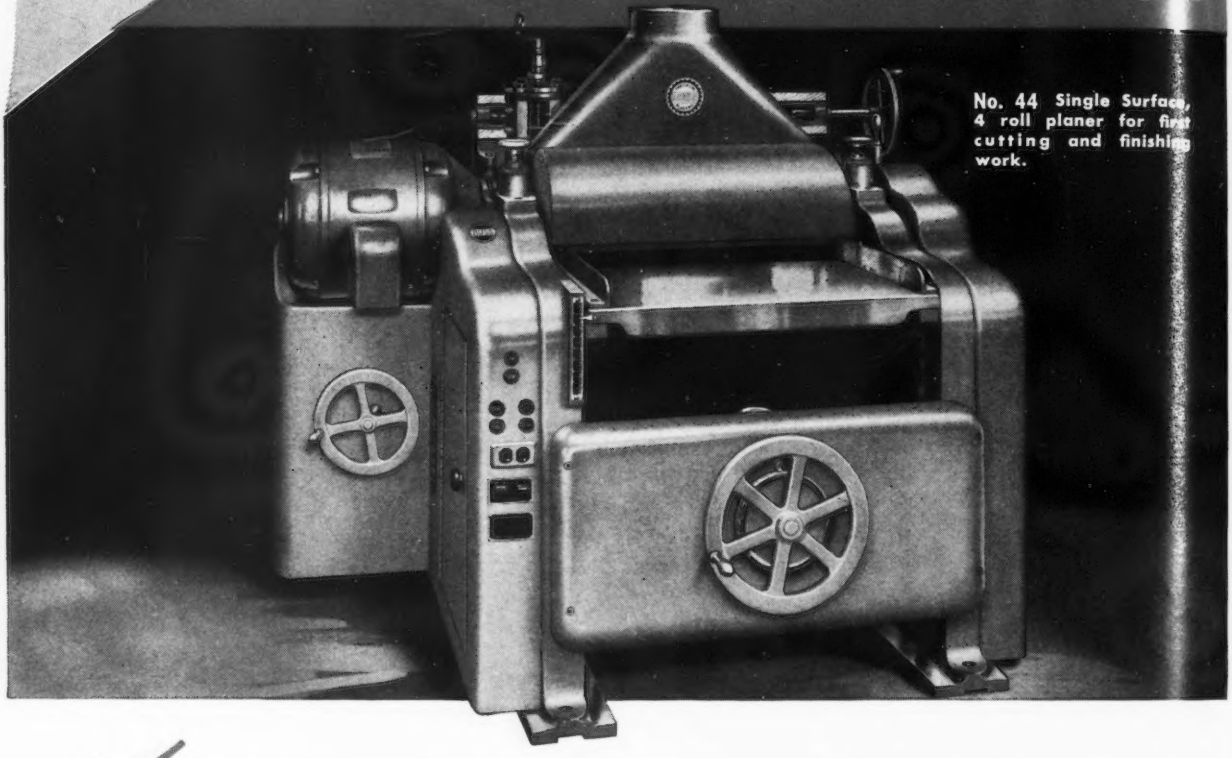
Dedication of FPRS Executive Office Building Opens Successful 12th National Meeting

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5 WISCONSIN

Check the Record!

THE BEST PLANER FEATURES ARE FOUND FIRST IN . . .

BUSS PLANERS!



No. 44 Single Surface, 4 roll planer for first cutting and finishing work.

In 1919 BUSS pioneered the use of *High Speed Ball Bearings in planers;* 1922, *Direct Motor on the Arbor Cutterhead Construction;* 1923, *Drop-Forged Sectional Chipbreaker and Roll;* 1925, *Multi-Speed Motor and High Frequency;* 1930, *Chrome Plated Wearing Surfaces;* 1935, *Built-in Reduction Unit,* eliminating fast-running gears; 1941, *Pressure Bar Micrometer Control* (patented); 1946, *Instantaneous Lower Roll Micrometer Adjustment;* 1948, *Shearing Bar* (patented); 1950, *Chipbreaker Micrometer Control* for adjustment of chipbreaker (patented); 1956, *Commercial production of 59" wide Double Surfacer;* 1950-58 *Special Production Surfacers.*

All the above are exceedingly valuable developments as proven in actual production and were *found first in BUSS planers.* Consequently, to be sure the planer you buy today is modern to the minute with all the features necessary to produce the most and the best planing at lowest cost, be sure it is a BUSS Planer. Write for bulletins or consult us and judge for yourself.

6 MODELS
40 SIZES

THERE'S A BUSS PLANER TO EXACTLY SUIT YOUR NEEDS

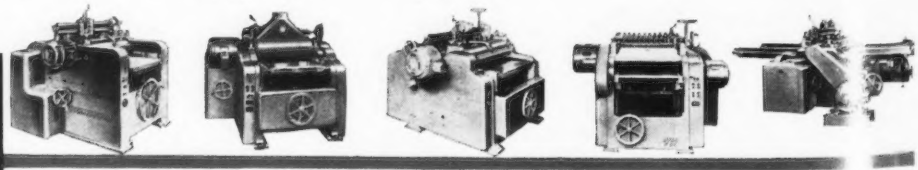
No. 4-L Single Surface, medium sized planer for first cutting and finishing work.

No. 44 Single Surface, 4 roll planer for first cutting and finishing work. **No. 66** — 6 roll.

No. 88 Double Surface, 8 roll planer for first cutting and finishing work.

No. 55 Heavy duty Double Surfacer for planing rough lumber.

MICRO-SURFACER for planing hardwood and other very thin materials.



BUSS
SINCE 1862
MACHINE WORKS

PLANER SPECIALISTS EXCLUSIVELY

292 EIGHTH STREET • HOLLAND, MICHIGAN

FPRS

Executive Officers

President
W. Jeter Eason, Memphis, Tenn.

President-Elect
E. S. Harrar, Durham, N. C.

Vice President
R. H. Berry, Burney, Calif.

Past President
F. H. Kaufert, St. Paul, Minn.

Executive Secretary
Frank J. Rovsek, Madison, Wis.

•

Regional Board Members

Southeast
W. L. Irwin, Pickens, S. C.

South-Central
W. R. Warner, Warren, Ark.

Northeast
D. K. Saunders, Westbrook, Me.

North-Central
J. J. Allegretti, Chicago, Ill.

Northwest
T. S. Veazey, Jr., Butte, Mont.

Southwest
F. E. Dickinson, Richmond, Calif.

•

Publications Committee

Chairman
Edward G. Locke, Madison, Wis.

•

Editorial Staff

Editor
R. H. Hamre, Madison, Wis.

Editorial Assistant
Sandra M. Parrini

THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin. Entered as Second-Class Matter, April 1952 at the Post Office, at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

FOREST PRODUCTS JOURNAL

Vol. VIII, No. 7 July, 1958

CONTENTS

Page

FPRS News—Digest ---------- 5-A

LUMBER MANUFACTURING

Can Lumber Compete? ----------J. S. Bethel and A. C. Barefoot 9-A
Engineering Approach to Logging and Milling ----------F. C. Simmons 14-A

WOOD PROPERTIES

The Swelling Pressure of Wood ----------H. Tarkow and H. D. Turner 193

DIMENSIONAL STABILIZATION

A Method for Dimensional Stabilization of Wood and Wood Veneer ----------W. P. Ericks 197

WOOD DRYING

High-Temperature Kiln-Drying of Lumber—A Summary of Canadian Progress ----------W. W. Calvert 200

WOOD STRUCTURE

Spiral Grain in Second-Growth Douglas-Fir and Western Hemlock --G. K. Elliott 205

WOOD PRESERVATION

Factors Affecting the Amount of Naphthalene in Condensate During Boiling Under Vacuum in Creosote ----------G. Bramhall and W. M. Connors 211

LOG GRADING

Tree Grade Cruising Possibilities from a Study in Second Growth White Oak ----------D. P. Worley, O. A. Schmidt, and A. R. Duhnkrack 214

VENEER AND PLYWOOD

Reducing Heat Distortion in the Knife and Pressure Bar Assemblies of Veneer Lathes ----------A. O. Fiehl 216

MATERIALS HANDLING

The Fork Lift Truck for Handling Forest Products ----------J. J. Beach, Jr. 19-A
Pallets Play an Important Part in Materials Handling ----------W. H. Sardo, Jr. 22-A

LAMINATES

Reinforced Plastics as Protective Coatings for Wood ----------R. Mark and B. M. Zuckerman 25-A

DEPARTMENTS

Meet FPRS's 100 Company Supporting Members ---------- 4-A
FPRS Employment Service ---------- 8-A
Around the World in Forest Products Research ---------- 27-A
Abstracts from Current World Literature ---------- 28-A
Index to Advertisers ---------- 30-A

IMPORTANT FPRS DATES

Aug. 21–22, 1958: Great Lakes Section Meeting, Houghton, Mich.

Sept. 26–27, 1958: Inland Empire Section Meeting, Missoula, Mont.

Oct. 12, 1958: Mid-South Section Meeting, Baton Rouge, La.

Oct. 27–28, 1958: Pacific Northwest Section Meeting, Vancouver, B. C.

Oct. 28, 1958: Northeast Section Clinic Meeting, Jamestown, N. Y.

Oct. 30–31, 1958: Northeast Section Meeting, Lancaster, Pa.

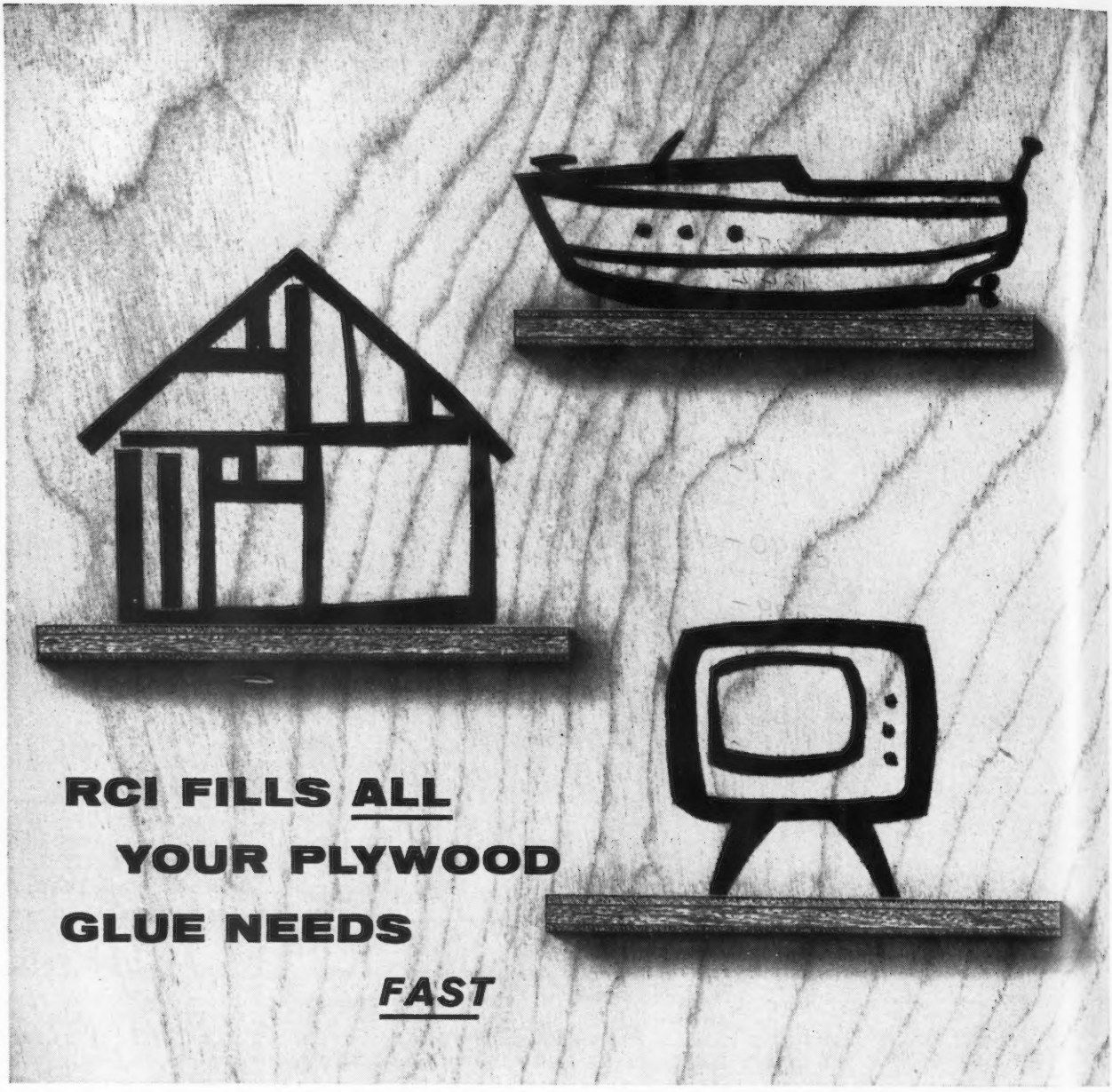
Nov. 6–7, 1958: Carolinas–Chesapeake Annual Section Meeting, Charlotte, N. C.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

On the Cover

Dedication ceremonies opened the 12th National Meeting in Madison. Shown on the cover facing the crowd (l. to r.) are: W. Jeter Eason, Nickey Bros. Inc., FPRS President and architect of the building; Mrs. Eason; R. H. Berry, Scott Lumber Co., Vice-President, and Fund Drive Chairman; Mrs. Berry, Mrs. Bescher; and R. H. Bescher, Koppers Co., a past president of the Society.

Dr. F. H. Kaufert, University of Minnesota, retiring president of the Society, presided at the dedication. To the right of the sign are: Otto Heyer, supervising architect; Wisconsin State Attorney General Stewart Honeck; Madison Mayor Ivan Nestingen; and Dr. J. A. Hall, Director, U.S.F.P.L.



● Whether you need phenol-formaldehyde, urea-formaldehyde, resorcinol or PVAc adhesives, soybean or casein glues, Reichhold can supply you. RCI has "the full line!"

When it comes to delivery, you can count on Reichhold for speed, too! Widely located RCI plants and warehouses can fill all your needs for any of these adhesives without delay...by rail tank car or highway tank wagon.

And you can be sure of uniform performance, because RCI control of adhesive quality extends to manufacturing its own basic raw materials such as phenol and formaldehyde.

When you have a technical problem, RCI's nationwide field service laboratories are ready to help you solve it . . . whether it involves a special glue for hot press, cold press, R/F, patching, splicing, utilizing wood waste or some completely new job.

Let Reichhold fill all your adhesive needs . . . technical information included!

REICHHOLD

Synthetic Resins • Chemical Colors • Industrial Adhesives • Phenol
Hydrochloric Acid • Formaldehyde • Glycerine • Phthalic Anhydride
Maleic Anhydride • Sebacic Acid • Ortho-Phenylphenol • Sodium Sulfite
Pentaerythritol • Pentachlorophenol • Sodium Pentachlorophenol
Sulfuric Acid • Methanol

REICHHOLD CHEMICALS, INC.,
RCI BUILDING, WHITE PLAINS, N.Y.

Creative Chemistry... Your Partner in Progress

RCI

THE BLACK BROTHERS

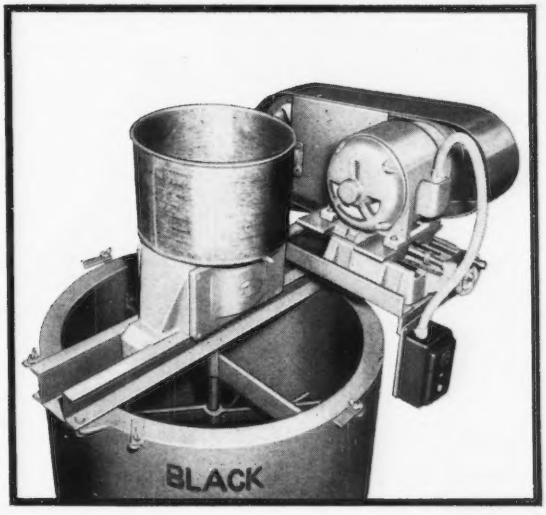
Cold glue MIXERS

FOR POWDERED OR LIQUID ADHESIVES

The Black Brothers stationary cold glue mixers are made in a full range of capacities from 10 to 500 gallons. They are the result of *expert engineering combined with years of practical experience in glue equipment manufacturing.* Their many special features include: (1) Sifter for glue powder (2) Double agitators which give a beating action resulting in the smoothest possible mixture in the least possible time (3) Pressure lubrication (4) Cut steel gears . . . hardened and lapped (5) Large quick-acting valve at bottom. For full information write today for Bulletin 11-I.

TWO-WAY AGITATION ▶

To the right is a partial view of a 60 gallon cold glue mixer arranged with a variable speed drive and water jacket. The covers have been removed showing accessibility for cleaning, and also the double agitator arrangement. Note the thick double walled tank permitting free circulation of water for cooling the glue batch.



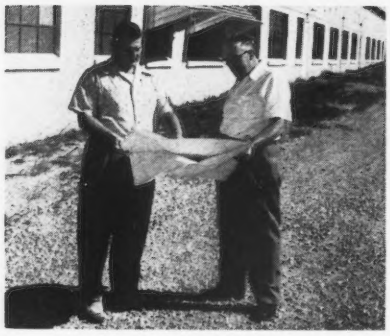
PORTABLE MOTOR DRIVEN GLUE MIXER ▶

The Black Brothers portable motor driven cold glue mixer is made in 2, 5, 7½, and 15 gallon sizes. It has a number of exclusive Black Brothers features such as a glue powder sifter, two-way agitation, and specially shaped flat paddles to give a beating action to the agitator. In addition this convenient, portable mixer has a hinged arm that may be swung up to allow the pail to be inserted or removed. This mixer is also being used extensively in the mixing of catalysts and hardeners. Write for Supplement to Bulletin 11-I.

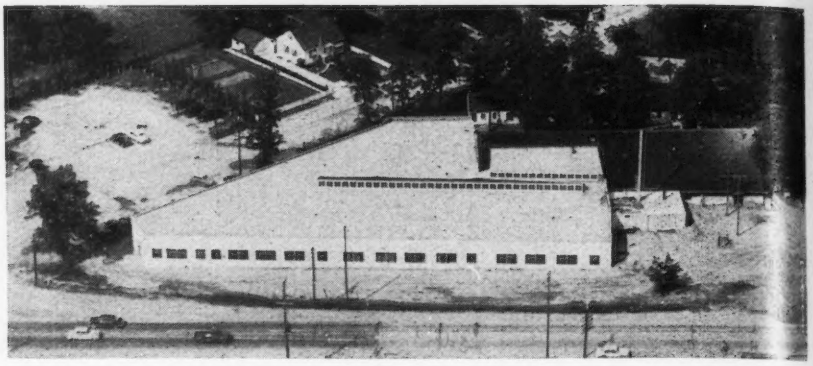
"If It Is Gluing Equipment — We Have It"

THE BLACK BROTHERS CO., INC.
MENDOTA 8, ILLINOIS

Decar Plastic Corp. Becomes Supporting Member at FPRS Meeting



George W. Johnson and T. Walter Noble



Aerial view of Decar Plastic Corp., Middleton, Wis.

Decar Plastic Corp. of Chicago, Ill., and Middleton, Wis., joined as a supporting member of the Forest Products Research Society during the National Meeting in Madison in June. The new membership was announced at the Annual Business Meeting, Tuesday, June 24. Vice president and plant manager George W. Johnson is the firm's designated representative to the Society.

Mr. Johnson, originally from Chicago, Ill., is in charge of production at the plastics firm. He has been associated with Decar Plastic Corp. since 1948. Previous to his association with Decar, he was with the Alleghany Steel and Brass Corp. Mr. T. Walter Noble, Vice president and technical director of Decar, was Food and Social Chairman for the recent meeting in Madison.

The firm produces Decarlite plastic laminates as well as complete tops for household, school, and office furniture. Decorative plastic is used for the functional surface over lumber core, plywood, particle board, and honeycomb construction. The surfaces are produced in wood grain or stylized patterns through the use of photographic reproductions on paper.

Upon completion of a new facility, Decar plans to move their entire woodworking operations to the new plant to enable the present facility to produce plastic sheets in a wider range of patterns, colors, sizes, and finishes. Construction of the new plant is scheduled to begin this year with completion planned for sometime in 1959.

Meet FPRS 100 Company Supporting Members

ALABAMA
International Paper Co., Mobile

ARKANSAS
The Crossett Co., Crossett
Dierks Forests, Inc., Hot Springs
Southern Lumber Co., Warren

CALIFORNIA
California Redwood Association, San Francisco
L. J. Carr & Co., Sacramento
High Sierra Pine Mills, Inc., Oroville
Ivory Pine Co., Dinuba
Scott Lumber Co., Inc., Burney
Ralph L. Smith Lumber Co., Anderson
Tartar, Webster & Johnson, Stockton

ILLINOIS
The Dean Company, Chicago
General Electric, Ill. Cabinet Plant, Rockford
Greenlee Tool Co., Rockford
Edward Hines Lumber Co., Chicago
Johnson & Carlson, Chicago
Masonite Corp., Chicago
Mattison Machine Works, Rockford
Sherwin–Williams Co., Chicago

INDIANA
The Dunbar Furniture Mfg. Co., Berne
National Homes Corp., Lafayette

KENTUCKY
Deluxe Saw & Tool Company, Louisville

MAINE
Moose Head Mfg. Co., Monson

MARYLAND
J. I. Wells, Salisbury

MASSACHUSETTS
Atlas Plywood Corp., Boston
Draper Corp., Hopedale
Heywood–Wakefield Co., Gardner
A. G. Spalding & Bros., Inc., Chicopee

MICHIGAN
Armstrong Machine Works, Three Rivers
Baker Furniture, Inc., Grand Rapids
The Dow Chemical Co., Midland
Everett Piano Co., South Haven

MINNESOTA
Mereen–Johnson Machine Co., Minneapolis
Minnesota Mining and Mfg. Co., St. Paul
Rilco Laminated Products, Inc., St. Paul
Timber Products Chemical Co., Minneapolis
Wabash Screen Door Co., Minneapolis

MISSISSIPPI
Richton Tie and Timber Co., Richton

MISSOURI
Monsanto Chemical Co., St. Louis

MONTANA
Intermountain Lumber Co., Missoula

NEVADA
Vaughn Millwork Co., Reno

NEW JERSEY
National Adhesives, Plainfield
Western Electric Co., Kearny

NEW YORK
American Defibrator, Inc., New York
Behr–Manning Corp., Troy, N. Y.
Borden Co., New York
Peter Cooper Corps., Gowanda
The New Jersey Industries, Inc., New York
Oval Wood Dish Corp., Tupper Lake
Pierce & Stevens Chemical Corp., Buffalo
Reichhold Chemicals, Inc., White Plains
United States Plywood Corp., Brewster
The Upson Co., Lockport

OHIO
American Machine & Foundry Co., Shelby
The Baldwin Piano Co., Cincinnati
Coe Manufacturing Company, Painesville
The Kirk & Blum Mfg. Co., Cincinnati

OREGON
Brooks–Scanlon, Inc., Bend
Cascades Plywood Corporation, Lebanon
Conroy Publishing Corp., Portland
Forest Fiber Products Co., Forest Grove
Georgia–Pacific Corp., Portland
Mater Engineering, Corvallis
J. Neils Lumber Co., Portland
Oregon Lumber Co., Baker
West Coast Lumberman's Assn.. Portland

PENNSYLVANIA
Kennametal, Inc., Latrobe
Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
United States Steel Homes, Inc., Harrisburg
Wood Metals Industries, Inc., Kreamer

SOUTH CAROLINA
Lightsey Brothers, Miley
Poinsett Lumber & Mfg. Co., Pickens

TENNESSEE
E. L. Bruce Co., Memphis
Chapman Chemical Company, Memphis
Memphis Hardwood Flooring Co., Memphis
Nickey Bros., Inc., Memphis

TEXAS
Wm. Cameron & Co., Inc., Waco
Kirby Lumber Corporation, Houston
Love Wood Products of Texas, Diboll
Southern Pine Lumber Co., Diboll

VERMONT
Beecher Falls Mfg. Corp., Beecher Falls

WASHINGTON
American Marietta Co., Seattle
Biles Coleman Lumber Co., Omak
Cascade Lumber Co., Yakima
Columbia Plywood Co., Inc., Seattle
Chelan Box & Mfg. Co., Chelan
Diamond Match Co., Spokane
Douglas Fir Plywood Association, Tacoma
International Paper Co., Long–Bell Division, Longview
Simpson Logging Co., Shelton
Sumner Iron Works, Everett
Weyerhaeuser Timber Co., Tacoma

WISCONSIN
Decar Plastic Corp., Middleton
Harnischfeger Corp., Port Washington
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh

CANADA
B. C. Forest Products, Ltd., Vancouver
British Columbia Lbr. Mfrs. Assn., Vancouver
Canadian Forest Products Limited, New Westminster, B. C.
Dominion Electrohome Industries, Ltd., Kitchener, Ont.
Knight Mfg. & Lbr. Co., Ltd., Meaford, Ont.
MacMillan & Bloedel Ltd., Nanaimo, B. C.

FPRS NEWS-DIGEST

Volume VIII JULY, 1958 Number 7

Over 600 Attend FPRS 12th National Meeting

AT THE OFFICIAL Luncheon are l. to r., W. Jeter Eason; Wisconsin Governor Thomson; Assistant Secretary of the Army Roderick; and Dr. F. H. Kaufert.

A TYPICAL TECHNICAL Session at the FPRS Meeting. Many sessions attracted more than 200 persons, and a good attendance was had by all sessions.

Basic Research Stressed at Madison Meeting

Five hundred and fifty research technologists, business executives, and educators participated in the highly successful 12th National Meeting in June at Madison. Sixty nine women registered for the ladies program, bringing the total attendance up to 619 persons.

An unusual facet of the meeting was the early arrival of guests, with many checking into hotels Saturday night. An estimated 150 persons attended the dedication ceremonies of the new FPRS Office Building, held Sunday afternoon, just one block from the U. S. Forest Products Laboratory.

"No other state can proudly claim to be the home of so much basic research that is so fundamental to the forest products industries", Wisconsin State Attorney General Stewart Honeck said at the dedication.

"With the Institute of Paper Chemistry at Appleton and the U.S. Forest Products Laboratory just a couple of hundred yards away, this permanent headquarters of the Forest Products Research Society helps to give Wisconsin its prominent position," he added. Mr. Honeck officially cut the ribbon.

In remarks at the ceremony, R. H. Berry, Fund Drive Chairman, told the assemblage that over $61,000 in cash and materials had been received for the building, exceeding by $1,000 the original goal of $60,000.

Others participating in the dedication were Dr. F. H. Kaufert, then president; W. Jeter Eason, president-elect and architect of the building; Dr. J. Alfred Hall, Director, U. S. Forest Products Laboratory; Otto Heyer, supervising architect; and Madison Mayor Ivan Nestingen.

Following the ceremonies, Mrs. Frank J. Rovsek, Mrs. Robert Hamre, and members of the FPRS staff, Mrs. Kenneth Arneson, and Mrs. Alvin Joyner, served refreshments to members as they toured the interior of the building.

THE GAVEL of office is presented to new president W. Jeter Eason by retiring president F. H. Kaufert.

Afterwards, 200 registrants and their families attended the Official Welcoming Reception at the Hotel Loraine. D. W. Bensend, chairman of the Mid-West Section, sponsors of the event, greeted guests at the reception.

Cooperation in Research Stressed

Approximately 350 persons attended the keynote session Monday afternoon. The cooperative roles in research that should be taken by government, industry, and education were discussed.

At the Official Luncheon, June 24, the theme of the meeting was carried through by Assistant Secretary of the Army Roderick who spoke to a capacity audience of more than 400.

Quoting the Commission on Increased Industrial Use of Agricultural Products Report to the 84th Congress with respect to wood, Mr. Roderick said, "Knowledge in this field . . . is still inadequate for the tasks ahead." Two major weaknesses exist, he added. First, the research forces directed to this purpose have been inadequate, and second, essential basic scientific knowledge is inadequate.

"Basic research, from which stem new developments, is truly an obligation of industry, educational institu-

tions, and government. Without basic research our commercial and industrial complex would soon be at a standstill and would stagnate," Roderick said.

Technical Sessions Well Attended

The 17 technical sessions were well attended with as many as 200 persons present at some sessions. Over 80 fundamental and applied research papers were presented. The Subject-Matter Division meetings also stimulated much interest.

Two Firms Become Supporting Members

Two firms joined the list of FPRS Supporting Members at the meeting. They are Decar Plastic Corp., Middleton, Wis., who will be represented by George W. Johnson, and Timber Products Chemical Co., Minneapolis, Minn., represented by Howard E. Olson.

Awards Given

Two Award of Merit citations were given by Hitchcock Publishing Co., publishers of Hitchcock's WOODWORKING at the Keynote Session. The Western Pine Assoc. and Timber Structures Inc., received the two awards. R. H. Berry accepted the award for the former.

Harry D. Tiemann received an honorarium of $300 from the Moore Dry Kiln Co. for presenting the lecture on "Highlights in the Development of Kiln Drying." The lecture was called the Charles J. Williams Memorial Lecture in honor of a past president of the Moore Dry Kiln Co.

American Institute of Wood Engineers Organized at Meeting

The nucleus of a professional society for graduates of forest products curricula was established during the FPRS meeting. It was tentatively named the American Institute of Wood Engineering. A temporary constitution was adopted and officers elected and instructed to draw up a permanent organization plan within the next two years. Because the objectives of the group are closely related to those of FPRS, the officers were instructed to seek means of affiliating the group with FPRS.

Officers elected were: J. S. Bethel, N. C. State College, president; H. O. Fleischer, U. S. Forest Products Laboratory, vice-president; R. L. Youngs, U. S. Forest Products Laboratory, secretary-treasurer; Fred Dickinson, University of California, trustee; A. Muschler, Edward Hines Lumber Co., trustee; and A. J. Panshin, Michigan State University, trustee.

Government Laboratory Major Attraction

During the meeting, 250 men and women attended open-house tours at the U. S. Forest Products Laboratory. Exhibits illustrated work of the laboratory, from increased utilization through improved growing and harvesting, to the search for new products from waste. Included in the tour was the hydrogenation laboratory where wood sugars are made into glycerine at high temperatures. A model of the internal fan kiln was shown, as was a veneer lathe in action.

Registrants were also able to hold consultations with laboratory personnel on technical and economic problems. Estimates indicate that over 175 persons availed themselves of this service during the week of the meeting.

Registrants were also able to visit other forest products facilities in Wisconsin and Illinois. Firms holding open house on Friday were: the Institute of Paper Chemistry, Appleton; Marathon Div., Rothschild; Kimberly–Clark Corp., Neenah–Menasha; Mosinee Paper Mills, Mosinee; Harnischfeger Homes, Inc., Port Washington; Allis–Chalmers Mfg. Co., Milwaukee; and Hammond Organ Co., Chicago.

Social Highlights

Social Highlights of the meeting were the Paul Bunyan hour and the FPRS Party at the Maple Bluff Country Club. Close to 500 persons attended the party and witnessed the Dona Runge Water Ballet, produced by Burmek Theatrical Productions, Milwaukee. Features of the entertainment were high diving, clown diving, and rhythmic swimming.

Executive Board Plans

The 1959 National Meeting will be held in San Francisco, June 28 to July 3. The 1960 meeting will be in Montreal, and the Executive Board voted to accept the invitation of the Society's Ohio Valley Section to hold the 1961 meeting at Louisville, Ky.

W. J. Eason Installed as Twelfth FPRS President

W. J. EASON

Mr. W. Jeter Eason, vice-president, Nickey Brothers Inc., Memphis, Tenn., was installed as FPRS President during the Official Luncheon at the 12th National Meeting in Madison. He succeeds Dr. F. H. Kaufert, University of Minnesota, who will remain on the Executive Board as Past President.

"The completion of our new office building marks a new era of maturity for the Society," Mr. Eason stated in his acceptance speech. The Luncheon was held in the Crystal Ballroom of the Loraine Hotel, June 24.

E. S. HARRAR

R. H. BERRY

President-Elect for the coming year is Dr. E. S. Harrar, Dean, School of Forestry, Duke University, Durham, N. C. Elected vice-president was Mr. R. H. Berry, Scott Lumber Co., Burney, Calif. Mr. Berry ended his term of office as Southwest Regional Board Member this June.

Regional Board Members

Mr. J. J. Allegretti, director of product development and market research, Masonite Corp., Chicago, Ill., was elected to a three-year term as North–Central Regional Board Member. A second regional board position was filled by F. E. Dickinson, director, University of California Forest Products Laboratory, Richmond, who will represent the Southwest Region of the Society.

Elected to the National Nominating Committee for 1958–59 were: Dr. A. A. Marra, Simpson Timber Co.; R. F. DeGrace, Canadian Institute of Timber Construction; L. A. Patronsky, Timber Engineering Co.; and L. N. Ericksen, California Forest Experiment Station.

Retiring Board Members

R. H. BESCHER

R. L. HILLER

R. H. Bescher, vice-president, Koppers Co., Pittsburgh, Pa., who held the position of past-president on the National Executive Board, retired from his post this June. Mr. Bescher was the 10th president of the Society.

Robert L. Hiller, American Cyanamid Co., completed a three-year term of office as North–Central Regional Board Member this June. Mr. Hiller served as General Chairman of this year's National Meeting at Madison.

Photo Highlights of FPRS 12th National Meeting

Over 600 persons registered for the FPRS Meeting in Madison. Seventeen technical sessions were held with over 80 papers presented. Nearly 200 consultations with U. S. F. P. L. staff were held.

Registration Desk at the Hotel Loraine during the meeting. Mrs. Dalton, FPRS staff, and Bernard Granum, Nat'l Meeting Comm., register guests.

A. L. Mottet, International Paper Co., Longview, Wash., presided over the Wood Composition Board Session, first of the meeting.

Dr. F. H. Kaufert started off the Keynote Session Monday p.m. L. to r. are: V. L. Harper, Winton Patnode, and Dr. J. A. Hall.

Harry D. Tiemann (right) receives honorarium from Pat Williams Jr., Moore Dry Kiln Co., following his lecture on Developments in Kiln Drying.

A capacity crowd of more than 400 persons attended the Official Luncheon in the Crystal Ballroom of the Loraine Hotel on Tuesday, June 24.

Assistant Secretary of the Army Roderick spoke to the assemblage on the importance of wood to the armed forces.

An Award of Merit Citation is presented to the Chicago representative of Timber Structures Inc., (left), by Louren Jouett, Hitchcock's WOODWORKING.

A Wood Award is presented to Howard Spalt, first place winner, by Jack F. Koellisch, WOOD & WOOD PRODUCTS. L. to r. are: George Garratt, Koellisch, Spalt, and W. R. Smith.

Registrants load on busses for the U.S. F.P.L. tours. More than 200 persons took the laboratory tours, and close to 200 held consultations with the staff.

Seasoning Exhibit at the U. S. Forest Products Laboratory attracted many during the tours on Thursday, June 26.

Water ballet troupe prepares for performance at pool, while members enjoy Paul Bunyan Social Hour held before the FPRS Party.

Guests line up at the buffet table during FPRS Party at the Maple Bluff Country Club. More than 500 attended.

Two Yale Students Win Wood Awards

Yale entries won first and second place in the 9th annual Wood Award Competition sponsored by WOOD & WOOD PRODUCTS magazine in cooperation with FPRS. The awards, given for outstanding graduate student research in forestry and wood technology, were presented by J. F. Koellisch, editor and manager of WOOD & WOOD PRODUCTS, at the Official Luncheon, during the 12th National meeting.

Spalt Wins First Award

First-place-winner Howard A. Spalt, New Haven, Conn., won $350 and a certificate for his paper on "The Fundamentals of Water Vapor Sorption by Wood". Mr. Spalt holds a B. S. from Rutgers University and a M. F. degree from Yale University, where he is presently a candidate for the degree of Doctor of Forestry.

Second-place Winner

"Strength Retention in Woods Decayed to Small Weight Losses" was the title of the paper by Robert W. Kennedy, Vancouver, B. C., Canada, who received the second place prize of $150 and a certificate. He is currently an instructor on the faculty of forestry at the University of British Columbia. He studied at Yale School of Forestry and has completed residence requirements for the Ph.D. degree. Dr. George Garratt, Yale University, accepted the award for Mr. Kennedy.

Three Receive Honorable Mention

The judges felt that, because the quality of this year's entries was so high, three papers should receive honorable mention. They are: "An Electron Microscope Investigation of Pit Membrane Structure in Conifers and Hardwoods—Its Implications in the Seasoning and Preservation of Wood" by W. A. Coté, New York College of Forestry; "The Strain Behavior of Wood Subjected to Repetitive Stressing in Tension Parallel to the Grain" by R. M. Kellogg, Yale School of Forestry, and "The Effect of Particle Geometry and Resin Content on the Bending Strength of Oak Flake Board" by P. W. Post, Pennsylvania State University.

Total Entries

A total of 13 entries, representing seven colleges and universities, was judged by a staff selected by Dr. James S. Bethel, chairman of the FPRS Industry–Education Division. Judges were: Walton R. Smith, Southeastern Forest Experiment Station, Asheville, N. C.; Arthur L. Mottet, International Paper Co., Longview, Wash.; and D. B. Richards, Alabama Polytechnic Institute, Auburn, Ala.

Award of Merit Judges

Some of the 40 nominations for the Award of Merit Citations are here being evaluated. Judges were (l. to r.): M. B. Pendleton, secretary–manager, National Hardwood Lumber Assoc.; Donald L. Davis, Sr., president, Aetna Plywood & Veener Co.; Herbert J. Joseph, Jr., treasurer, Handy Mfg. Co.; and C. W. Billingsley, media director, Fuller & Smith & Ross Inc.

Northeast Section Plans Two October Meetings

Two fall meetings are planned by the Northeast Section, J. Allen Hauter, program chairman reports. A clinic on "Trends in Furniture Design, Materials and Methods" will be held at Jamestown, N. Y. on October 28, for the members of the Jamestown Area Furniture Mfgs. Assoc.

On October 30 and 31, a meeting will be held at Lancaster, Pa. at the Hotel Brunswick.

Timber Science Departments Consolidated at New York State College of Forestry

E. A. ANDERSON

A Wood Products Engineering Department has been established at the State University College of Forestry at Syracuse, which consolidates the college's basic and applied timber science departments into a single organization, college officials announced recently.

Chairman of the new department is Dr. Eric A. Anderson, professor of wood technology, who joined the faculty from the U. S. Forest Products Laboratory in 1950. The major programs leading to the B. S. degree from the department are: manufacturing, marketing, wood mechanics and physics, and wood anatomy.

Resources include 14 teaching and research men from the Forest Utilization and Wood Technology Departments, and facilities of the Hugh P. Baker Wood Products Laboratory.

News–Digest Continued on page 29-A

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–312—Superintendent or plant manager needed with experience in hardwood dimension manufacturing including mouldings and interior trim. Opportunity to acquire an interest in a 39-year-old concern. Northern location. (July)

E–314—Teaching position in wood products available. Courses to be taught include wood machining, quality control, and production management. Research in some aspect of these fields will be expected. Doctorate degree or equivalent experience in teaching, research or industry and an engineering background are desired. (Aug.)

E–315—Teaching position in wood products available. Courses to be taught may include primary forest products, lumber manufacture and distribution, possibly seasoning and logging. Research in some aspect of these fields will be expected. Doctorate degree or equivalent experience in teaching, research or industry and an engineering background are desired. (Aug.)

Employment Wanted

No. 472—Research, teaching or production position desired. Holds BS in general forestry and will complete work on a masters degree in wood utilization in August from a major school. Has some research experience in both forestry and wood utilization. Northern location preferred. (July)

No. 473—Production or industrial engineering position desired. Holds BS in wood utilization from N. Y. State College of Forestry. Experienced as an industrial engineer and time standards analyzer in a cabinet plant. Prefers Northeast location. (July)

No. 474—Position desired with firm producing laminated structures, plywood and similar products. Holds BS in Forestry with Wood Utilization option. Now serving as a Naval Officer and will be available for work in September. North-Central or Northwest-Central location preferred. (July)

No. 475—Plant position desired. Holds a BS in Forestry and has five years experience in wood preserving industry. Prefers northeast or North Central location. (July)

No. 476—Executive position in production or development desired. Is a F.C.T.C. technologist. Has 20 years experience in wood products, plastics to wood, resin and adhesive manufacture, particle board and wood finishes. Will locate anywhere in Canada. (July)

FPRS Forest Products Journal

Vol. VIII, No. 7
July, 1958

Can Lumber Compete?[1]

J. S. BETHEL and A. C. BAREFOOT

Director, Wood Products Laboratory, and Assistant Professor, School of Forestry, North Carolina State College, Raleigh

With increasing use of materials such as plastics, aluminum, stainless steel, and others in construction and consumer products, where does lumber stand in terms of product, price, and quality? If lumber is to maintain its competitive position, basic changes must be made in the manufacturing processes to reduce costs and improve quality.

LUMBER IS THE MOST IMPORTANT wood product manufactured in the United States—in terms of quantity. Over one-half of all round wood processed is converted into lumber. The volume of lumber manufactured in American sawmills annually is approximately 40 billion board feet. Quite obviously, the lumber industry is a big industry and its continued health is important to the economic well-being of the nation.

In contrast to many other large industries that produce raw materials for commercial use, the American lumber industry does not have the potential of substantial growth in terms of total annual output in the immediate future. The situation with respect to supply and demand as it relates to the lumber industry in terms of past history and future prospects has been the subject of several comprehensive studies (1, 2, 3)[2] during recent years.

These studies indicate that America's lumber requirements will continue to be large. The President's Materials Policy Commission (1) found that: "Despite increasing use of many competing materials, lumber remains indispensable in building construction, ship building, furniture manufacture, and dozens of other enterprises." This Commission went on to point out, however, that: "Timber used to be even more important in the national economy." This study indicated that, whereas the annual growth of all types of timber almost balanced drain, the situation with respect to saw timber was critical. Here drain far exceeds growth, and consequent higher costs have edged timber out of uses to which it is well adapted. Exhaustible materials have taken the place of renewable timber because they are cheaper.

The Timber Resource Review, (3) in discussing future requirements for wood, points out "that lumber, the dominant element in future requirements, must be obtained from trees of saw timber size." It further indicates that "in the future, as at present, the major portion of the wood needs of the United States will come from trees above the minimum saw timber sizes." From the viewpoint of the requirements of the lumber industry, it is important to note that the distribution among diameters of trees cut is not the same as the distribution of standing timber. Better forest management may ultimately result in an increase in the volume of large-diameter, saw timber quality trees, but this cannot occur in a short period of time. The current trend is toward the use of smaller logs for the production of lumber. The Stanford Research Institute (2) recognized this when, in making its estimate of wood products supplies, it assumed a decline in the average size of logs cut in all regions of the United States.

All studies (1, 2, 3) of supply demand relationships in the lumber market have assumed that the demand for lumber will continue to be high, provided that it can be marketed at a reasonable price with respect to the price of competitive materials.

Generally, the price of lumber has increased much more rapidly than that of other basic materials. The President's Materials Policy Commission found that, while the wholesale prices of all commodities increased 109 per cent from 1940 to 1950, the price of lumber advanced 218 per cent. During this same period, the prices of aluminum, iron ore, nickel, and copper showed an increase less than the average of all commodities. The Stanford Report[2] indicates an increase in lumber prices between 1929 and 1952 of 286 per cent. According to this study, the price of cement increased about 20 per cent, the price of gypsum products increased about 50 per cent, and the price of competing construction materials generally increased about 90 per cent during this same period.

The underlying causes of the price increases sustained by lumber during the past several years are many. Some of them are subject to limited control by the industry, but many are not. One of the principal reasons for increased lumber prices has been rising stumpage prices. The Stanford Report states that stumpage prices have increased more than 500 per cent during the period 1929 to 1953. This increase in stumpage value in part reflects competition among wood-using industries for raw material. An increasing number of sawmills are bidding against each other for a continually diminishing supply of good saw timber. Furthermore, other wood industries such as the pulp and paper industry and the veneer and plywood industry are also competing for some wood that could be converted into lumber. The greater stumpage prices are also in part due to the fact that virgin timber is rapidly disappearing from the American scene, and in many regions of the country it has already disappeared. Second-growth timber must be sold at stumpage prices that return to the owner the cost of producing the wood.

The costs of processing the wood have also increased. Labor costs have increased for the lumber industry as for all industry. In some areas where the lumber industry still pays wages

[1] Presented at Session X, Lumber Manufacturing, of the FPRS Eleventh National Meeting, held June 23-28, 1957, in Buffalo, New York.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Authors: James Bethel holds a BS degree from the University of Washington and MF and DF degrees from Duke University. He was associated with the U. S. Forest Service, Penn. State College, Virginia Polytechnic Institute, and Tidewater Plywood Co. before joining N. C. State as Professor of Wood Technology in 1949. Bethel is Chairman of the FPRS Carolinas-Chesapeake Section and Industry-Education Division.

A. C. Barefoot holds BS and MS degrees in wood technology from N. C. State College, and a DF from Duke University. He received one of the NLMA Teco Scholarships in 1951. He has been on the faculty of N.C. State College since 1954.

substantially below its competitors in the labor market, labor rates may increase very substantially in the future. Manufacturing costs generally have increased and may be expected to continue to rise.

It is reasonable to assume that lumber prices will continue to increase more rapidly than those of most of its competitors. If lumber is to continue to sell in its present volume and yield a reasonable return on investment, its price cannot increase as it has in relation to the prices of competing materials. The Stanford Report indicates that "if the price of lumber increases at the same rate in the future as it did between 1939 and 1952, it will have about priced itself completely out of the market by 1975." This statement is based on the assumption of an increase in the price of competitive materials at the same rate in the future as in the past.

The picture, then, of projected supply and demand in the lumber market is one of a relatively fixed supply of raw material that cannot be appreciably increased even with very substantial price increases, and demand that will equal this supply unless prices increase to the point where even expensive substitutes can capture the market.

In this situation, the lumber industry must attempt to decelerate prices as compared to competitive materials, and it must offer its customers a better and more useful product to justify those price increases that are inevitable.

As has already been pointed out, the only reasonable expectations for the foreseeable future are increases in the cost of stumpage and labor. These represent two of the most important components of lumber cost. Accordingly, reductions in lumber manufacturing costs will be achieved with difficulty and are not likely to be spectacular. This does not mean, however, that they are not possible nor that they are not worthy of working for. In general, cost savings in the manufacture of lumber fall into two general categories:

1. Reduction in wood costs through improvements in yield of saleable product.
2. Reduction in labor costs as the result of lowering the number of man hours required to produce a board foot of lumber.

Improving Yield

That portion of lumber cost attributable to wood value can be minimized by increasing the number of board feet of lumber produced from a given volume of stumpage, and it can also be minimized by increasing the volume of other products produced from saw timber trees.

Log Cut-Up: The volume and value of lumber and other products obtained from a given tree may vary over a wide range, depending upon the wisdom and skill used in determining how the tree is cut up into logs and bolts. This is one activity in lumber manufacture where judgment plays a leading role. Unfortunately, in most of the lumber producing areas very little attention is devoted to this decision-making activity. In fact, it is comman for these decisions to be made by the most unskilled labor available. Studies currently in process at the North Carolina Wood Products Laboratory indicate that substantial increases in yield and profit can be obtained through the use of linear programming methods to arrive at the optimum procedure for converting trees to logs and bolts. These techniques make it possible to develop a set of rational log-making rules that can be given to unskilled woods labor.

Log Break-Down: It has long been recognized by the lumber industry that the decisions with regard to log breakdown made by the sawyer can effect yield and product value. Normally, the best paid and most skilled labor employed in the mill is assigned to this task. The studies previously mentioned have shown nevertheless that linear programming techniques can be useful in maximizing yield and profit in this decision-making activity.

The development of more uses for narrow widths and shorter lengths will increase the opportunities for increasing lumber yields. Greater use of laminating, scarfing, and finger-jointing techniques promises to permit higher yields.

Multiple-Products: The use of residues of the lumber manufacturing process to produce other useful products is proving to be one of the best ways of increasing yields and total product value. In almost all lumber producing areas of the country, there are opportunities to sell tops, weed trees, and very small trees for pulpwood. Many lumber manufacturers, however, are still not taking advantage of these opportunities.

The introduction of log and slab debarkers into the lumber producing facility makes it possible to chip such residues as slabs, edgings, and trimmings and sell them for pulp manufacture. Planing-mill shavings are being used effectively in a few areas for the production of dry-formed particle boards.

The lumber manufacturer who takes advantage of these opportunities to use more of the saw timber tree not only increases yield and product value for the trees that he processes, but he also enhances his opportunities to obtain additional saw timber. As has been already pointed out, the lumber industry faces a real problem in obtaining adequate supplies of saw timber. Large areas of forest land are owned by pulp and paper companies. These companies are much more likely to grow saw timber size trees and make them available to lumber manufacturers if they are able to get substantial quantities of pulp wood and pulp chips from sawmill residues.

Sawing Processes: Lumber yields can be increased by decreasing saw kerf loss. Increased use of band and gang saws in the East and South may offer opportunities to accomplish this. What is a more apparent trend in this direction is the use of a band resaw with a medium-sized circular sawmill. This combination has been making its appearance with increasing frequency during recent years, particularly in the South.

Better dimensional accuracy in the lumber manufacturing process will also contribute to improved yield of lumber, since it necessitates smaller allowances for dressing out. This subject will be treated more fully later in this paper when quality is discussed in detail.

Reducing Man-Hour Requirements

The best opportunities to combat rising labor costs in the manufacture of lumber lie in improving the manufacturing facility so that the number of man-hours required to produce a board foot of lumber is reduced. This is not a simple procedure in the face of a decline in log sizes, but some outstanding successes in achieving this objective made by a few manufacturers have demonstrated that it can be done.

Logs, timbers, and lumber are essentially bulky items, and unless sound engineering principles are fully utilized to plan materials handling procedures properly, much expensive labor will be used in the conversion process. Large sawmills have frequently been well equipped for mechanized materials handling. Small portable sawmills have notoriously been deficient in mechanical equipment for handling logs and lumber. The trend in the country generally is away from these extremes. In the West, more and more use is being made of medium-sized sawmills to supplement or in some cases even replace large installations. As multiple products become more a feature of the lumber manufacturing operation in the South, the medium-sized permanent mill is proving to be more efficient than the highly portable small mill. Success in meeting the challenge of high labor costs will depend to a very real extent upon the ability of

the industry to adapt mechanical materials handling methods to medium-sized mills.

Large bridge cranes and railroad cranes and heavy, steam-operated log-deck equipment cannot be used with medium-sized sawmills. Small portable cranes and fork and straddle trucks are being adapted to material handling in the log and lumber yard. Pneumatic, hydraulic, and electrical niggers, log stops, and log loaders and log turners are available for installation on medium-sized mills to accomplish, with relatively small labor demand, the log-handling operations required on the log deck. The small and medium mill must make extensive use of conveyors (roll, chain, belt and elevator) to move material in the lumber-producing process.

Perhaps one of the most fruitful areas for small and medium mill development is in plant layout. The practice of operating all equipment used in a small portable mill from a single mandrel has made equipment layout and arrangement almost inflexible, and has contributed much to inefficiency in labor utilization at these mills. A study recently conducted at North Carolina State College showed that at a large number of portable mills the only laborer whose time was used at all efficiently was the sawyer. Most of the remaining labor could be used efficiently only if the individual items of equipment could be separately powered to provide freedom in selecting and arranging the location of auxiliary equipment. Separate power plants on auxiliary equipment have been shown to be practical even for portable mill installations. The combination of re-saws with circular mills permits flexibility in plant layout that permits efficient utilization of labor.

Product Quality

While increases in product yield and reductions in man-hour requirements are essential if the lumber industry is to remain competitive, there appears to be no possibility of achieving a long-term reduction in lumber prices.

If lumber is to be sold at a profit and at an increasing price, it is essential that the industry make a real effort to establish standards and control quality in accordance with these standards to the advantage of the potential lumber consumer. Quality of lumber can be expressed in terms of grade and of such measurable properties as dimension and moisture content.

Lumber Grades

The lumber industry has long been handicapped in its efforts to compete with materials that are formulated in that it has described its product in terms of a wide variety of complex grades. These grades are not only not understood by most lumber users, they are not even well understood by many people in the lumber industry itself. Johnson (4) summarized the problem of lumber grades as follows:

> "The multiplicity and complexity of grades and grading rules has created serious problems in the marketing of lumber. The industry has recognized that fact for many years. Back in 1922, an effort was made to solve the problem by the establishment of American Lumber Standards only partially solved the problem. They standardized sizes and provided a broad general base grade classification for softwoods, but they did not provide standard grades. There are still 20 or more sets of regional grading rules, each of which contains a number of grade specifications that are not exactly duplicated in any other set of rules. In addition, two different basic principles are used in grade descriptions. They are description by example and by specification. The first describes the grade by use of typical examples of the type of boards the grade contains, the second specifies the permitted defects and specifically limits their size. The wide difference in the character of lumber in grades of the same name results in confusion, is annoying to buyers and users, and is the source of controversies as to the comparability of grades of different species."

In addition to the problem created by the multiplicity of lumber grades, there is a companion problem that reflects the continuing reduction in the average grade of sawlog available to the industry. Lumber grades have changed very little over the course of a great many years. As the quality and size of sawlogs has changed, the grade recovery has also changed. The proportion of boards in the upper grades is very small as compared to what it was when most lumber came from virgin timber. Accordingly, the price of the scarce upper grades has increased very substantially and many consumers now must use lower grades. Sometimes these grades are suitable and sometimes they are not. Sometimes minor changes in grade requirements would increase the volume of material available and permit lower prices in the upper grades. In any event, the psychological reaction on the market is bad.

It has been argued that grades are so well established within and without the country that to make major changes in the grades either for the purpose of simplifying them or of reflecting current log quality would result in chaos in the market. There seems to be little reason to believe that this would be true.

The Douglas-fir plywood industry is an example of an industry that has been able to change its grade specifications successfully at regular intervals to reflect changes in log quality, manufacturing methods, and market requirements. Admittedly, the task of revising the lumber grade structure would be a great one. The time to do it is long overdue. Character markings that do not materially effect the utility of the lumber should be acceptable in the highest grades and best cuttings. The grade structure should be prepared to provide for a reasonably high recovery of the upper grades. Grades should be simplified so that consumers can readily understand them. Grading rules for similar woods should be combined to reduce the number of unique grading rules. Grades should be based upon current market requirements to the extent that they are compatible with the quality of currently available sawlogs.

This constitutes a recommendation for relaxation of specified standards, but it should be pointed out that this applies to standards that are related to the quailty of raw material.

Another area of specification relates to variables that are a function of manufacturing processes. In this area there is little excuse for relaxation of standards, and in fact every reason to take advantage of improved technology to tighten specification requirements. It has been the history of most materials that, as technical progress has been made in manufacturing methods, tolerances for measurable qualities have been tightened to yield a product more acceptable to the consumer. Qualities that can be controlled in manufacture have thereby been improved. Open-hearth carbon-steel rails, for example, in 1916 were required by ASTM standards to have a carbon content in the range of 0.50 to 0.63. By 1952, this requirement had been changed to 0.55 to 0.68. Hardwood and softwood plywood specifications have been changed to relax many grade requirements to reflect changes in log quality, but have shown a continuous improvement in specified glue line qualtiy, which reflects improvement in the quality of adhesives and gluing techniques. Similar examples could be obtained for other materials. In the case of lumber, there has been no improvement in standards for thickness and width since American Lumber Standards was initiated in 1924, and in fact there is at least one instance of retrogression.

American Lumber Standards in 1925

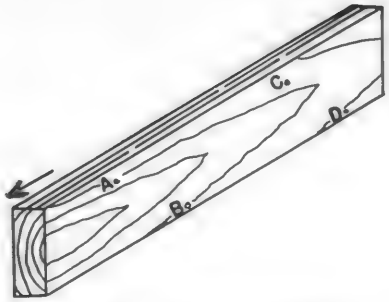


Fig. 1.—The points at which thickness is measured on each board.

described mis-cutting as variation in sawing in excess of:

1/16" in 1 inch material
1/8" in 2 inch material
3/16" in 3 to 7 inch material
1/4" in 8 inch material and up

In 1956, the specifications for mis-cutting in American Lumber Standards remains the same. The clear implication is that during this 30-year period there has been no improvement in sawmill machinery that would improve its accuracy, and accordingly no way to improve the specification.

The National Hardwood Lumber Association grading rules show the following examples of specifications for mis-cut hardwood lumber for 1945, 1955, and 1956.

Nominal board thickness	1945	1955	1956
1/2"	1/16"	1/16"	1/8"
3/4"	1/8"	1/4"	3/16"
4/4"	1/4"	3/8"	1/4"
7/4"	1/4"	3/8"	1/4"
8/4"	1/4"	1/2"	3/8"
4//	1/2"	5/8"	5/8"

This represents a clear retrogression that opposes a general trend toward better quality control for competitive materials.

It is worthwhile to examine the process capability of present-day lumber manufacturing equipment in terms of dimensional accuracy. Mis-cutting in the sense that it is usually used in the lumber industry is a function of within-board thickness variation. Fig. 1 illustrates a method of measuring the thickness of boards produced in a sawmill. If four measurements are taken at the points indicated, the statistic σ^1 can be computed by

$$\sigma^1 = \overline{R}/d_2$$

where $\overline{R}$ is the average range for a series of board measurements, σ^1 is the standard deviation of the individual measurements, and where d_2 is a constant that depends upon sample size. The standard deviation computed in this way provides a measure of the ability of the mill to produce a uniformly dimensioned board once the saw has begun to cut. Table 1 gives standard deviations calculated from data for several types of mills reported in the literature (5, 6, 7, 8). These data show that the gang mill is generally the most accurate, with band mills next in accuracy and circular mills least accurate. It should be noted that some of the circular mills are more accurate than the poorer band mills.

Even though some circular sawmills do produce accurate lumber, it is generally true that this class of equipment produces the bulk of the mis-cut lumber. Since a very high percentage of the nation's lumber supply is produced on circular mills, and since the number of these mills is increasing, it is appropriate to investigate more thoroughly the process capabilities of mills of this type now in use. In 1953, the U. S. Forest Products Laboratory collected data on lumber thickness from 84 sawmills located in 26 states representing all areas of the United States. These data were submitted to the North Carolina Wood Products Laboratory for statistical analysis. Table 2 summarizes the data from these sawmills in terms of the standard deviations of thickness measurements within boards. These data on process capability indicate that a high percentage of circular sawmills in the country have very poor control over the dimension of rough lumber. There is, however, good evidence that circular sawmills can control dimensional accuracy. The better circular mills examined by the U. S. Forest Service were controlling dimensions as closely as is commonly done in good band and gang mills.

Many small sawmills and possibly some larger mills rely on excessive board thickness to insure acceptance of rough lumber. This contributes to low yields and excessive costs and is one of the reasons for high lumber prices. Bethel, Barefoot and Stecher (9) have shown that good quality control procedures can be used to control board thicknesses and thus eliminate

Table 1.—WITHIN-BOARD VARIATION AS MEASURED BY STANDARD DEVIATION IN 1/32 OF AN INCH

Type of mill	in 1/32 inch
Norwegian gang mill (5)	0.302
Norwegian gang mill (5)	0.088
Norwegian gang mill (5)	0.151
Norwegian gang mill (5)	0.391
Norwegian gang mill (5)	0.164
Norwegian gang mill (5)	0.164
Norwegian gang mill (5)	0.151
American gang mills (7)	.657
American double-cutting band mill (7)	0.573
American single-cutting mill (6)	1.378
American single-cutting mill (6)	1.048
American circular mill (6)	1.542
American circular mill (6)	1.262
American circular mill (6)	1.129
American circular mill (6)	1.488
American circular mill (6)	1.057
American circular mill	1.305
American circular mill (8)	1.238

Table 2.—SAWMILLS BY REGIONS AND THEIR STANDARD DEVIATIONS

Forest Service Region No.	State	Mill No.	in 1/32 inch	Regional High	Regional Low
1	Montana	1	2.300	2.300	1.472
		2	1.919		
		3	1.472		
4	Utah	1	2.343	2.343	2.343
6	Oregon	1	2.645	2.645	1.472
		2	2.280		
		3	1.758		
		4	1.517		
		5	1.472		
	Washington	1	2.086		
		2	1.604		
		3	1.581		
7	Maine	1	1.208	2.879	0.4
		2	.479		
	Kentucky	1	2.879		
		2	1.961		
	Maryland	1	1.702		
		2	1.387		
	New Jersey	1	1.756		
		2	1.267		
	New York	1	1.113		
		2	1.083		
		3	.893		
	Pennsylvania	1	1.647		
		2	1.582		
		3	.898		
	Virginia	1	.900		
		2	.841		
		3	.810		
		4	.444		
	West Virginia	1	1.367		
		2	1.336		
		3	1.245		
		4	1.133		
8	Alabama	1	3.014	3.942	
		2	2.495		
		3	2.315		
		4	1.722		
	Arkansas	1	2.834		
		2	2.006		
		3	2.696		
		4	1.875		
		5	1.816		
		6	1.697		
		7	1.946		
		8	1.116		
	Florida	1	3.293		
		2	2.545		
		3	2.470		
		4	2.240		
	Georgia	1	1.891		
		2	1.574		
		3	1.557		
		4	1.317		
	Louisiana	1	2.834		
		2	2.605		
		3	2.191		
		4	.963		
	Mississippi	1	2.610		
		2	2.505		
		3	1.831		
		4	1.462		
	North Carolina	1	2.596		
		2	2.036		
		3	1.996		
		4	1.572		
	South Carolina	1	2.271		
		2	1.976		
		3	1.944		
		4	1.537		
	Tennessee	1	3.942		
		2	1.622		
		3	1.577		
		4	1.312		
	Texas	1	2.612		
		2	2.290		
		3	2.166		
		4	2.154		
9	Illinois	1	1.327	2.250	1
	Michigan	1	1.169		
		2	1.128		
	Minnesota	1	2.110		
	Wisconsin	1	2.250		
		2	1.911		

Table 3.—PROCESS CAPABILITY TABLE FOR SMALL SAWMILLS [1]

Standard deviation in 1/32 of an inch	Proportion of pieces expected to fall inside the indicated tolerance limits when the process is properly centered: 1/8"	3/16"	1/4"	% of sample mills in each class
0.0 –0.75	1.000	1.000	1.000	2.38
0.75–1.25	1.000	1.000	1.000	16.67
1.25–1.75	1.000	1.000	1.000	28.57
1.75–2.25	.830	.989	1.000	25.00
2.25–2.75	.626	.936	.994	19.05
2.75–3.25	.442	.830	.970	5.95
3.25–3.75	.309	.694	.915	1.19
3.75–4.25	.217	.563	.830	1.19
4.25–4.75	1.54	.442	.732	100.00%

[1] These data assume a process in a state of statistical control, that is, no between subgroup variance exists or is extremely small as compared to a within subgroup variance. There is no method for properly evaluating process capability in sawmills operating out of control.

the need for excessive thickness to meet minimum specifications.

If arbitrary tolerance limits are set on individual measurements and a sawmill's capability is known, then the proportion of acceptable pieces of lumber expected to fall inside the tolerance limit can be calculated when the entire process is properly centered and the process is in control. Table 3 illustrates such a tabulation for the 84 sawmills included in the Forest Service survey.

This analysis considers only the within-board variation and assumes that the between-board variation is of the same order of magnitude as the within-board variation. Excessive between-board variation would result primarily from deficiencies in the setting equipment or technique. The summary shows that a substantial percentage of the sampled circular sawmills are basically capable of producing quite accurate lumber.

Table 4 shows data on five circular sawmills studied by the North Carolina Wood Products Laboratory. These data illustrate the improvement in process capability that can be achieved when good quality control procedures are utilized.

If the lumber industry is to maintain a strong competitive position, it must undertake to give as much value as possible for the price it charges for its product. One method of accomplishing this is to improve dimensional control. This will permit improvement in yield and consequently a lower cost per unit of product. It will also provide a more uniform and accordingly a more acceptable product.

Some improvement in manufacturing standards can be obtained through better mill management. A great opportunity for improvement in manufacturing standards lies in improvement in sawmill equipment. It is not the purpose of this paper to develop in detail new developments in lumber manufacturing equipment. An analysis of recent developments in industrial technology in competitive industries suggests some possibilities for the improvement of lumber manufacturing equipment. Many sawmills could be materially improved through the use of better materials and better parts in their fabrication. Sawmills generally are susceptible to re-design to achieve better mechanical controls. For example, the use of automatic feed-back mechanisms that instantaneously correct for errors in cutting would result in better control of dimension. A sawmill that operated on the principle of a fixed carriage and a moving saw might provide for more precise manufacture and better equipment arrangement. There are many other possibilities for improving manufacturing equipment that are worth exploring.

Table 4.—VARIATION WITHIN MEASUREMENTS IN SMALL CIRCULAR SAWMILLS

Mill	Out of control	In control	
	2.57	1.12	
	2.62	1.51	
	1.46	1.46	improvement in x chart only
	2.04	1.51	
	1.94	1.65	

The incentives required to bring about improvement in the design and construction of sawmill equipment are higher manufacturing standards developed, promoted, and enforced by the industry itself.

Conclusions

In summary, it would seem that the demand for lumber will continue to be high, provided that its price does not become excessive. The supply of lumber available in the next 20 years is relatively fixed and is not likely to become appreciably increased even in response to price increases. Increases in stumpage and labor costs appear to be certain, and lumber prices must therefore be increased. Accordingly, lumber, if it is to be sold at a higher price and with a reasonable profit, must be more useful and attractive to potential consumers. The industry should undertake to simplify grading rules so that they are easier for the consumer to understand. Grading rules should also be modified to reflect the present quality of sawlogs and current uses for lumber. These changes in grade should be accompanied by improved standards for quality characteristics that are related to manufacturing methods such as dimensional tolerances.

Literature Cited

1. President's Materials Policy Commission. 1952. Resources for Freedom.
2. Stanford Research Institute. 1954. America's Demand for Wood.
3. U. S. Forest Service. 1955. Timber Resource Review.
4. Johnson, R. P. A. 1950. Grading problems that challenge the lumber industry. Proc. FPRS. Vol. 4.
5. Klem, Gustav G., and Martin Seem. En Undersokelse av Skurnoyaktigheten ved Forskjellige Sagbruksty per. Norse Treteknisk Institute. Meddelelse Nr. 3.
6. Davis, E. M. Studies of variation in sawing. U. S. Forest Prod. Lab., Madison, Wis.
7. Data courtesy Western Pine Association, Portland, Oregon.
8. Telford, C. J. 1952. Small sawmill operator's manual. USDA Agriculture Handbook No. 27.
9. Bethel, J. S., A. C. Barefoot, and D. A. Stecher. 1951. Quality control in lumber manufacture. Proc. FPRS.

Discussion

J. F. Hamilton Michigan College of Mining and Technology: Wouldn't you say that, in order to remain competitive, the lumber producing industry will have to apply a scientific approach to its problems and employ properly qualified personnel to exploit improved procedures, processing, and equipment?

Mr. Barefoot: If the mill wants a technical man they have to obtain this man early, possibly in high school, and then see that he gets through college. If the lumber industry is going to compete, they are going to have to get technical men in the industry.

M. H. Mater (Mater Machine Works): Mills on the West Coast are promoting good men and engineers, and are encouraging them to get into the wood industry.

E. P. Ivory (Ivory Pine Co.): I have been working with this problem for years, and find that owners and managers must have the feeling that they want to improve. I bring men in from the planing mill to check sizes in the mill and discuss problems with them.

C. O. Latimer (Nickey Brothers Inc.): What is the incentive for cutting rough lumber accurately?

Mr. Barefoot: There is incentive in the pride of doing a good job, which usually results in fewer miscuts, better centering, and thus more lumber.

P. Heller (Pacific Pine Co. Ltd.): We had a circular mill overrun of 8 per cent yearly. Adding a gang, the overrun went to 12 per cent; keeping equipment in good shape, overrun went to 3 per cent more, or 15 per cent overrun.

Mr. Ivory: Were figures on best and worst mills based on variation within boards or between boards?

Mr. Barefoot: Within boards.

Mr. Ivory: How do you think buyers would react to lowering the grade limits?

Mr. Barefoot: Specification rearrangements may be a better name. They must simplify rules and promote familiarity with common-sense decisions.

Mr. Heller: Lowering grades and simplifying is a very difficult job and will take years to do.

W. C. Irwin (Poinsett Lumber Co.): You say you can save lumber through quality control. If you lose 1/32 inch in each board, it takes 32 boards to gain an inch. How many people make 32 cuts in a log?

Mr. Barefoot: You can't save too much there but you save the miscuts that otherwise would be lost. You save in over-all production. It has been shown that useful production can be increased 10 to 11 per cent by using statistical quality control techniques.

Mr. Bethel: Increased width comes into this also.

W. L. Lear (Crossett Lumber Company): It has an effect on grade in pine. There are not so many skips.

Fred Simmons (Northeastern Forest Experiment Station): Width is very important, and 1/32 inch saved gives 2½ per cent more lumber. This has been proved.

John Reno (Pacific Lumber Co.): If someone can show us where we can save 1/32 inch, we'll pay them a lot of money.

Engineering Approach to Logging and Milling[1]

FRED C. SIMMONS

Specialist in Logging and Primary Processing, Northeastern Forest Experiment Station, Upper Darby, Pa.

The technical aspects of logging and sawmilling have long been overlooked. The engineering approach includes more than mechanization, however. It also consists of proper forest management, intelligent utilization of all obtainable products, competent personnel management, careful selection of equipment and methods, and thorough job planning.

LOGGING AND MILLING HAVE, until recently, been treated like the proverbial red-headed stepchild by many of the wood-using industries. Even in some of the most progressive integrated concerns, personnel qualifications and salaries in these departments have been low, capital expenditures for new and modern equipment have been kept at a low level, and the resultant obvious inefficiencies have either been ignored or passed off as being unavoidable. Processing plants that buy their lumber in the open market have been even less concerned about efficiency in logging and milling. Generally they have seemed to believe that all they could do was buy what was offered to them, regardless of its quality of manufacture or its price. The result has been that the quality of raw material for those industries buying woods—run lumber has become poorer and poorer, and the price for those buying on grade has become higher and higher.

There are many reasons for these conditions. It is true that in many places local stands of uniformly high quality timber have become scarce. Alternative sources, in many cases, have not proved to be any better. Even shifting to tropical forests as a source of supply has proved disappointing to many users. The labor supply for woods and mill operations is also becoming a more serious problem year after year. Men are no longer willing to work at tough jobs, with little or no opportunity for family life, at comparatively low rates of pay.

Trying to compensate for these conditions by price increases is no longer possible, in most cases. Today's economy is too highly competitive and there are too many other materials ready and willing to take over wood's markets when the price becomes too high. Trying to compensate for them by expedients and changes in secondary processing activities has its limitations too. End and edge gluing, lamination, plugging and patching, and concealing imperfections by overlays and opaque finishes are all costly, and in some respects unsatisfactory.

How then can we get more suitable material for the wood-using industries at a price they can afford to pay? Many concerns are finding that the one great remaining opportunity for improvement, now yielding rich rewards, is through the application of the same type of engineering principles to woods and sawmill operations that have been so successful in secondary processing activities. This engineering approach includes not only wise use of the techniques of mechanical and civil engineering, but those of administrative and human engineering as well. They are finding that successful use of this engineering approach is making it possible to attract and to keep good men in the woods and at the sawmills, men that would otherwise be lost to other industries. They are finding that the well-engineered operation makes it possible to upgrade a considerable portion of their cut, both in the woods and at the mills, and to guarantee a steadier supply of more suitable raw material for secondary processing plants. In addition, it provides an opportunity for additional income from sale or use of the byproducts of the mill and the woods operations.

This does not mean that every concern that uses wood should go out and

Fig. 1.—The post-war advent of the one man power chain saw had made the piece work fellers and buckers the aristocracy of the woods. *Photo courtesy Titan Saw Co.*

[1] Presented at the Fall Meeting of the Carolinas-Chesapeake Section, held Oct. 31, 1957, in Roanoke, Va.

The Author: F. C. Simmons received his BS degree from Cornell and his MF from the Yale School of Forestry. He is presently chairman of the FPRS Logging Division. Simmons is author of the USDA Northeastern Loggers Handbook, Bulletin on Sawmill Techniques, and numerous papers on logging and sawmilling.

s art a logging job and sawmill of its
wn. Some, undoubtedly, would be
ell advised to do so. It does mean
at every wood-using industry should
concerned with the efficiency and
liability of its sources of supply of
rest products, and that it should do
erything it can to understand the
oblems involved and to help in their
lution. A realistic and well-consid-
ed purchase policy, including for-
ulation and application of clear spec-
ications for the quality of material
ually needed, and contracting for ac-
tance of definite quantities of suit-
le material in advance, is a big help
creation of reliable and efficient sup-
iers. Many secondary wood process-
ng plants are shifting to the purchase
cut-to-size stock to suit their re-
uirements, in place of lumber.

Application of the Engineering Approach

The engineering approach to logging and milling involves far more than mechanization alone. A bewildering variety of mechanical devices for these types of work has become available in recent years. Selection of the right type and size for the task to be done is often critically important. But even when the right equipment has been selected, mechanization sometimes creates more problems than it solves. In many states, for example, both accident frequency and severity have increased as logging jobs and sawmills have been mechanized. The men operating the new mechanical equipment had been either poorly selected or insufficiently trained for the jobs they were called upon to do. Also, mechanization of one phase of a job frequently creates a bottleneck somewhere else along the line.

The objectives and methods of forest management, important as they are in assuring a future supply of raw material, are outside the scope of this paper. But the engineering approach to logging and milling will insure that these activities are conducted in accordance with the principles of good forest management. A well-engineered logging operation, for example, will remove only the trees that should be taken from a forest stand in harvest and improvement cuttings, or thinnings, and it will devise ways to make as complete and intelligent use of all the products obtainable from those trees as is possible. On a selective cutting job, the removal of trees to be cut will be done with the least possible damage to other trees left in the forest to make future volume and value growth. When clear cutting is being practiced, the well-engineered logging operation will create the best possible conditions for the regeneration of the forest.

Fig. 2.—Many mechanical devices are used by the contractors in loading and hauling. *Photo courtesy Shawnee Claw Co.*

The engineering approach to logging and milling involves the selection of competent and aggressive management personnel, and delegation of suitable authority to such personnel, with the lines of authority and responsibility clearly defined. It means careful and intelligent selection of equipment and methods to be used, based on conditions to be met and objectives to be accomplished. It includes careful planning of each job, and development and application of clear specifications for woody material to be segregated for various uses. It involves selection and training of the work force for each phase of the job. And it includes provision for periodic and sudden revision of plans and methods when conditions change. Such changes may be brought about by changing markets, new developments in machinery, a change in forest management policy, or a thousand and one other things.

Adaptability of These Principles

Perhaps one might think, "This is all very fine for the big and well-financed company, but it doesn't apply to the smaller operator. He can't afford competent supervisory personnel or good equipment. He doesn't have use for the variety of products that can be produced from the trees cut."

The small timber operator can do a good engineering job on his operations, however. In fact, in an increasing number of cases, he can't afford not to do such a job. If he isn't big enough to be able to afford good supervisory personnel he can make himself into a good supervisor. Wisely selected, suitable equipment, now available in sizes and at prices suitable for the smaller jobs, will pay for itself in a surprisingly short time. And a little digging around and developmental work will often result in finding markets for byproducts that were previously thought not to exist.

In the Northeast, the wood-using industry is made up preponderantly of small operators. They turn out only about a tenth of the Nation's forest products, but they are doing this in a highly industrialized area where wage rates are high, stands are light and scattered, the topography is rough, and weather conditions are severe. After 300 years of logging, the cut is increasing year after year. To a considerable extent the area is serving as a pilot plant where solutions are being worked out to conditions that will be prevalent in other regions or countries in years to come. Visitors from the West Coast and from Europe and Asia have indicated that this is the case.

In June, 1957, the representatives of some other regions were taken on a tour of a number of selected wood-using industries in the Adirondack Mountains of New York State. One of the visitors' major impressions was the extent to which capable and progressive young foresters and engineers had assumed active direction of logging and sawmilling activities, either as independent operators or as employees of the generally small wood-using firms along the route. They were also impressed with the extent to which these firms, which required different types of forest products, were cooperating with one another in their wood procurement problems. There are a few big integrated wood-using industries in the Northeast, like the Brown Company in New Hampshire with its sulfite and sulfate pulpmills, hardwood and softwood sawmills, and hardwood plywood plant.

Fig. 3.—The recent introduction of the four-wheel-steer, four-wheel-drive skidding tractor is contributing to lower cost and more efficient logging. *Photo courtesy R. G. LeTourneau, Inc.*

But generally, integration is being accomplished among small independent industries by recognizing and segregating material more suitable for use by the other fellow in the woods or at the mill, and by selling or trading such material to the industry that can use it to the best advantage. The result is that wood-using industries are continuing to get raw material of the type they require at prices they can afford to pay, from second growth and culled over stands in a region where labor costs are high and logging conditions are tough. Further improvement in efficiency of operations and completeness of utilization is possible, in fact it is essential. It will be accomplished by continued cooperation among the different wood-using industries, the research agencies, and the equipment manufacturers. The Northeastern Loggers' Association, which includes all of these groups, is an important factor in this development.

What specifically is being done? As in any experimental and developmental program, there are many variations in methods being tried, and contradictions in the results secured. The Association is slowly learning what the important variables are, and which method will work best under any given set of conditions and with any given set of objectives.

Logging

First Stages of Mechanization: Many operations are in the first stages of mechanization. Much of this mechanization, in fact, has been introduced by the workers themselves on jobs where various phases of the work are contracted out on a piece-work basis.

As in other regions, getting felling and bucking done on most jobs is no longer a problem. The post-war advent of the one-man power chain saw has made the piece-work fellers and buckers the aristocracy of the woods. They are turning out two to three times the production that their predecessors did with a crosscut or bow saw, and they continue, by and large, to get the same or slightly higher piece-work rates per thousand or per cord. Earnings of $200 a week are not uncommon.

But felling and bucking in this way, with productivity the only goal, has created problems elsewhere along the line, particularly in skidding. Many piece-work fellers just don't make any attempt to do directional felling. They leave a jackpot of logs and slash, crisscrossed in every direction. This makes it difficult to do log length skidding, and practically impossible to skid economically in full tree lengths.

Most contract skidding on such jobs is done with tractors by ground twitching in log lengths. Scoots for logs, and drays for cut-to-length pulpwood are commonly used in parts of New England. Frequently, the tractors used with these scoots or drays are equipped with booms and winches to make assembly of the load and loading of these devices faster and easier. Even so, the contract skidder often has difficulty producing as much with his tractor as the feller and bucker does with his chainsaw. Sometimes the boss has had to take over this skidding phase of the job to get it done.

Many mechanical devices are used by the contractors in loading and hauling. Self-loading trucks, with "timber tossers" mounted on their sides or jib booms overhead are common among log haulers. Many pulpwood haulers have equipped themselves with simple conveyor loaders to carry the shorter lengths up onto the truck bed. Some contract haulers provide revolving boom cranes or fork lift trucks for loading.

These simple mechanized jobs are a big improvement over the hand and horse methods formerly used. They are a long way, however, from a completely engineered job.

The Present-Day Engineered Job: The present-day engineered jobs, big or small, have been laid out beforehand. The cutters know where the skid trails will be located, and they lay the trees down in herringbone style on either side so that they can be pulled out endways, without necessity for switching them around. Most skidding on such jobs is being done in full tree lengths.

This tree-length system of operation has many advantages. Tractors are able to skid more nearly a capacity load in tree lengths than in log or pulpwood lengths. Also, a more economical job of bucking is possible when the tree length is out in the open and up on skids than when it is back in the woods among standing trees, rocks, stumps, gulleys, brush and other obstacles. A more intelligent job of bucking is possible too. It is easier to train and supervise a crew to buck for maximum quality and quantity of the product desired when this activity is concentrated at a point out in the open. One northeastern plywood company reports that it is getting 20 per cent more high grade veneer logs since bucking was transferred to the landing. Many hardwood lumbermen have found that their value yield of lumber has been upped 20 per cent or more when crews trained in the principles of the Forest Service's "Hardwood Log Grades For Factory Lumber" are doing the bucking at the landing.

Not only is recovery of premium-priced material made more efficient by tree-length logging, but much additional material, suitable for pulp chips, charcoal, or other uses, is literally given a free ride to the landing on these tree lengths, and thus becomes available for industrial use there for little more than the cost of loading and hauling. Under log-length methods, this material would have been left in the woods as expensive-to-recover logging residues.

Many foresters have feared that tree length skidding would be more damaging to the residual stand than skidding log length or shorter material. There is, of course, the possibility that this could be the case. Lack

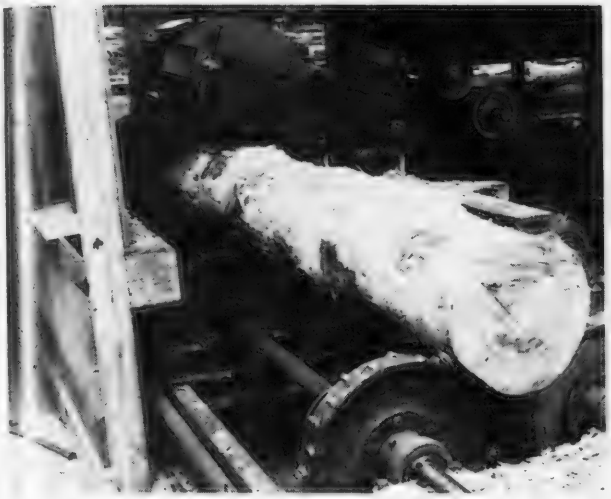


Fig. 4.—Several makes of mechanical log barkers, which can be completely installed and put into operation for less than $12,000, are now available. *Photo courtesy U. S. Forest Service.*

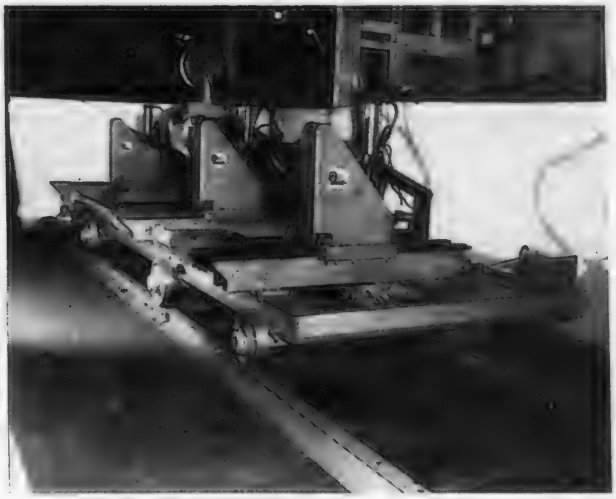


Fig. 5.—An automatic riderless carriage suitable for sawmills that cut between 10 and 20 thousand board feet per day. *Photo courtesy of Culvert Machine Service.*

planning and organization in felling and skidding on the tree-length jobs can create a lot of damage. Such unplanned jobs, however, are also more costly. Directional felling reduces bunching damage, and it also reduces costs. Skidding tree lengths down a well laid out and reasonably straight skid trail reduces the skinning of bordering trees, and it also reduces breakage of the material cut, and reduces costs.

The obvious solution is a well-planned job and a crew that works as a unit, rather than independently on the various phases of the job. This latter objective is usually attained by paying the entire crew on a piece-work basis for the volume bucked and ready for loading, or paying crew members by the hour, with a bonus for over-all productivity. When this is done, the fellers have an incentive to lay the trees down so that they can be skidded out most expeditiously, and the felling, skidding, and bucking crews cooperate to eliminate other bottlenecks, and in helping each other out when any member of the crew falls behind.

On this type of job, logging costs are generally lower, and damage to residual trees is very much less than it is on the log-length jobs. On many northeastern operations, the mileage of skid trails needed for tree-length operations is only 30 per cent of that needed when the material is brought out log length from comparable stands.

The recent introduction of the four-wheel-steer, four-wheel-drive skidding tractor is also contributing to lower cost and more efficient logging on such jobs. These rubber-tired tractors, which travel at speeds of around 12 miles an hour, both loaded and unloaded, have practically eliminated the initial truck haul through the woods on many northeastern operations. Skidding of tree lengths is being done over distances of 3 to 5, and even 7 miles. This reduces the number of necessarily large landing areas needed for tree-length operations, and eliminates the cost of constructing truck roads through the woods, which often runs $5,000 to $7,500 a mile. It also eliminates the wear and tear on trucks traversing these rough roads. The tractor trail that replaces them is usually built for about $100 a mile, since it involves only the cutting a a tree here and there, perhaps corduroying a boggy place, or knocking off the point of a ledge or two. By and large, the wheeled skidding tractors build their own roads. One operator in Maine, who has a fleet of these rubber-tired machines, claims that his cost of transport, from stump to mill, has been reduced 50 per cent since he started using them.

Loading and hauling, on these engineered jobs, are being improved in other ways. Loading is usually done by a revolving boom crane or a tractor with lift arms on the front, which can gather material from the large landing. The trend is toward use of bigger and better hauling trucks, equipped with such specialized devices as safety trip stakes, and hydrotarders to save the brakes going down steep grades. Bundling and palletizing have proved useful in expediting the loading of small logs and wood.

Future Developments: All this is resulting in the delivery of more suitable material, at a lower cost, not only to the sawmills, but also to the veneer mills, pulpmills, charcoal plants, and other wood-using industries. Further developments are in prospect. New and improved equipment items are becoming available almost every day, as a result of development by research laboratories, equipment manufacturers, and the loggers themselves. Revolutionary changes in techniques and equipment are possible, including use of helicopters, transmission belts, and pipelines. Chipping in the woods is being experimented with in several places.

A few operators are experimenting with full tree logging, including the tops, as practiced in Russia and advocated by Koroleff. Generally, these experiments have been aimed at reducing limbing costs rather than economically recovering limbwood. One Adirondack operator found that, by bringing in full spruce trees behind his wheeled tractor at speeds of around 12 miles an hour, he lost 50 per cent of the limbs on the way to the landing. Consequently, the bucker at the landing was able to remove the remainder of the limbs economically, and the total costs of spruce pulpwood, ready for loading, were $1 less a cord than they had been when limbing was done back in the woods. A pulpwood operator in Pennsylvania, working in hardwoods that had been chemically treated the previous year to expedite removal of the bark, found that full-tree logging practically eliminated all need for limbing effort, because the now-brittle limbs were "shucked off" in felling and skidding.

Perhaps some day loggers will be bringing in the entire tree and recovering useful material not only from the stem and limbs, but from the leaves and needles and the roots as well.

Sawmilling

Current Status: To date, engineering improvements in the woods have been adopted more widely and more rapidly than similar improvements in sawmills. Now, however, the stage is set for widespread changes in sawmill

equipment, methods, and products. These changes are long overdue. Worker pay in the woods has far outrun that in the mills, yet many mill operations are unprofitable. A case in point arose in the winter of 1956 at an operation in the St. Lawrence Seaway area in New York State. New aluminum plants in the next town, with a minimum wage of $3.50 an hour, were making it impossible to maintain a sawmill crew. The highest paid men in the mill were only earning $3.50 an hour, despite the fact that this was a band mill, well equipped by the standards of ten years ago. The average worker on this mill's woods operations was earning the equivalent of $5 an hour on a piecework basis. The mill manager said, "We've got to mechanize and automate our mill, and diversify our products, so that we can pay a higher wage, or go out of business".

Fortunately, the equipment for such an automatic mill setup, and for increasing the salable products of such a mill, is now available. A plan was mapped out for installation of log barking and chipping facilities, for installation of an automatic carriage, improved conveying equipment, and a new edger and chipper. The result should be production of about the same volume of lumber with about half the crew required by the present mill. In addition to the lumber output, there will also be production of about half a cord per M. of premium pulp chips, salable to nearby paper manufacturers, and a ton per M. of sawdust and shavings, salable for use as bedding to neighboring dairy farmers.

A competitive sawmill about 50 miles away has already automated its equipment, and reduced its work force on the mill floor from 17 to 7 men, including the filer. It has not yet installed a barker, or up-to-date lumber handling facilities, but these improvements are planned.

Both of these are band mills sawing about 20 thousand board feet a day. Other northeastern mills in this size class and larger are also rapidly modernizing their facilities.

Opportunities For Small Sawmills: The real news is that similar automatic equipment is now becoming available for smaller mills, with circular headsaws, sawing as little as 10 thousand board feet a day. Mills of this size, permanently located in small communities and obtaining their logs on a sustained-yield basis from surrounding forests, are a very important part of the northeastern wood-use economy.

Several makes of mechanical log barkers, which can be completely installed and put into operation for less than $12,000, are now available. Any mill sawing a million and a half feet a year can hardly afford to be without one of these machines, even though debarking does not make its slabs and edgings more readily salable. Debarking, even in a small mill, rarely costs more than $2 per M. Many mill operators are now convinced that debarked logs are worth something like $5 a thousand more to them than logs with the bark on. Records of such mills indicate that, since shifting to debarked logs, they are saving around $50 a week in saw bit, shank, and filing costs; that they have upped lumber productivity as much as 20 per cent; and that they have increased lumber yield, in comparison to log scale, as much as 10 per cent. This is primarily because the dirt and grit embedded in the bark and never thoroughly removed by log ponds or washers are now taken off along with the bark. Consequently, saw teeth last longer between sharpenings, and sawing all the time with sharp teeth increases accuracy of cutting. Lodging of loose bark between the cant being sawed and the knee or bolster is also eliminated. This last is one of the most common causes of miscut lumber.

Automatic deck equipment, hydraulic or pneumatic log turners, and air dogs and air electric setworks are also available now at prices the smaller mills can afford to pay. Automatic conveyors and lumber sorters, electronically controlled edgers and trimmers, and even automatic stackers and unstackers are being installed at these small mills. Such equipment makes it possible to double or even triple the productivity of labor at the mill, and at the same time improve accuracy of cutting.

Future Developments. The sawmill industry of the future, particularly in the hardwood areas of the East, will no doubt continue to be made up primarily of fairly small sized units, perhaps in the 10,000 to 20,000 foot a day class, permanently located, completely mechanized and partially automated. Mills of this size can obtain their log supply economically, on a sustained yield basis, around thousands of communities. To operate the automatic equipment, the labor in such mills will not have to be so physically strong, but it will have to be a lot smarter than the labor is in the manually operated mills of this size today. This mental alertness will not only pay off in the effective use and maintenance of the new equipment, but it will also result in more accurately cut lumber of higher grades from the same type of logs that are being cut today. Time and again it has been proven that the value yield of hardwood logs can be increased as much as 25 per cent by intelligent placement of the logs on the carriage, use of taper attachments, and timely log turning. These operations are made easier by the new devices. One New York State operator says he is going to train competent young lumber graders to operate his new automatic headrigs instead of old-time sawyers. This will probably pay off.

At the same time, these new type mills will produce material amounts of other forest products as raw material for other types of wood-using industries. Debarked slabs and edgings will go to central chipping plants for conversion into high-quality chips for pulpmills and particle board plants. Veneer-quality logs will be recognized, and sent to veneer and plywood plants. Bark-free sawdust and shavings will be processed for wood flour, or other industrial use, or for use in agriculture. Even the bark has possibilities of specialized use, or use as industrial fuel or agricultural mulch and soil improver.

Conclusion

Other new developments in both logging and milling suitable for either general or specialized use could be enumerated, but enough has been said to emphasize the point that there are now tremendous opportunities to improve these activities to the point where they will keep pace with advancements in secondary processing of forest products. Some progressive managements of both small and large operations have already embraced some of these opportunities. Many of them have not. It is increasingly essential, however, that wood procurement and primary processing be brought into step with the modern industrial revolution if wood is to be kept in the forefront among modern industrial raw materials, and particularly so if its position is going to improve.

The Swelling Pressure of Wood[1]

HAROLD TARKOW and H. DALE TURNER

Chemist and Chemical Engineer, Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

Apparent swelling pressure, always less than theoretical or true swelling pressure, has little theoretical significance, since it depends on experimental procedure and wood species. True swelling pressure is determined by restraining the swelling of wood substance. Apparent swelling pressure increased with increasing specific gravity to 11,000 psi at 1.44 between 30 and 100 per cent relative humidity. This value is believed to be fairly close to the true swelling pressure.

THE TENDENCY OF WOOD to swell and shrink is pronounced. It is responsible for many of the defects that develop in wood. Conventionally, swelling is expressed in terms of swelling capacity—that is, the maximum linear or volumetric swelling of which it is capable. Of equal importance is swelling pressure. It is more difficult to measure, and its experimental determination has been generally avoided. Barkas[3] in England has used the property to explain adsorption hysteresis and seasoning collapse.

General Discussion of Swelling Pressure

The driving force responsible for the penetration of moisture into a solid is due to the net effect of two factors. One pertains to the ability of the vapor to interact (energetically) with the solid. If heat is evolved, $(\triangle H)$, this factor is active and, unless overly compensated by the second factor, adsorption occurs. The second factor pertains to the tendency for all systems to approach maximum molecular randomness; that is, for the entropy to increase. This is the factor responsible for the "swelling" of one gas in another. It is responsible for the "swelling" of an aqueous solution when it is separated from water by a semipermeable membrane. It is responsible for the swelling of rubber in benzene. This latter example is particularly interesting because there is no significant energy of interaction between rubber and benzene; that is, the first of the two factors is approximately zero. The effectiveness of the second factor is given by $-T\triangle S$, where T is the absolute temperature and $\triangle S$ the difference in entropy between that of the dry solid and separate water vapor and that of the solid containing the water vapor. The total tendency for adsorption is the sum of both factors:

$$\triangle F = \triangle H - T\triangle S \qquad (1)$$

where $\triangle F$ is the driving tendency or the change in free energy accompanying adsorption. The tendency exists when $\triangle F$ is negative. The calculation of $\triangle F$ with equation (1) can be made only for certain nonpolar systems. With polar materials, such as water and wood, the calculation cannot be made with present information. Consider a finite amount of wood substance in equilibrium with water vapor at pressure P_i. Let the wood be placed in an atmosphere of saturated vapor, P_o; adsorption occurs. Suppose a hydrostatic pressure is applied when the wood substance is exposed in P_o. The extent of swelling will be reduced. At some critical hydrostatic pressure, P_c, no swelling will occur. P_c is the maximum swelling pressure of the wood substance under the given conditions of P_i and P_o. P_c is independent of the amount of wood substance, but depends only on P_i and P_o. It will be called the true swelling pressure to differentiate it from the experimental or apparent value.

Suppose the amount of wood substance is infinite and the hydrostatic pressure, P_c, is reduced by an infinitesimal amount. Swelling will occur. When 1 mol of water has been adsorbed, the wood will have swollen roughly by a volume $\overline{V}$, the molar volume of water, Since the adsorption of $\overline{V}$ by the infinite amount of wood substance does not alter the value of P_i, the swelling pressure is still P_c, and the mechanical work gained is $P_c\overline{V}$. $P_c\overline{V}$ is equal to $\triangle F$ of equation (1). Thus, the term "swelling pressure" has a thermodynamic meaning. It is measured by determining the minimum hydrostatic pressure that must be applied to prevent swelling just as the true EMF of a battery is that opposing EMF which must be applied to prevent flow of current. The swelling pressure is theoretically related to the initial and final vapor pressure:

$$P_c = \frac{RT}{\overline{V}} \ln \frac{P_o}{fp_i} \qquad (2)$$

where R is the gas constant, T is the absolute temperature, and f is an activity factor that under certain conditions may be set equal to unity.

Experimental Procedure

Principle: The experimental requirement is one whereby wood can be clamped to restrain swelling, yet be exposed to 100 per cent relative humidity. This can be done by making use of the high anisotropy of wood. A longitudinally cut cylinder of wood swells transversely. Longitudinal swelling is very small. A clamp can be applied to restrain transverse swelling while the end grain is exposed to the saturated water vapor.

Preparation of Wood: Blocks of yellow birch, 4–1/2 by 1–1/2 by 3/4 inches in size and straight-grained to minimize longitudinal swelling, were conditioned at 30 per cent relative humidity; then they were pressed transversely (with side restraints) at 160° C. for 1/2 hour at various pressures. After being reconditioned at 30 per cent relative humidity, the blocks in one density class were laminated to an over-all thickness of 1–1/2 inch with a cold-setting resorcinol glue, which gave a very thin glue line. The purpose of using laminated wood rather than solid wood was to facilitate reconditioning after the wood was hot-pressed. The specific gravity of the laminates varied from 0.69 to 1.42 at 30 per cent relative humidity.

[1] A contributed paper (December, 1957) based on work conducted at the U. S. Forest Products Laboratory. The present address of Mr. Turner is Masonite Corp., Laurel, Miss.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Barkas, W. W. The swelling of wood under stress. H. M. Stationery Office, London, 1949.

The Authors: Harold Tarkow holds a PhD from the University of Wisconsin. Formerly associated with the Portland Cement Association and Bradley Polytechnic Institute, he has been at the FPL since 1943, where he has been doing work on the dimensional stabilization of wood and on adhesion.

H. Dale Turner holds a BS in chemical engineering from Iowa State College. He held positions with the Forest Products Lab., Treschow-Fritzoe Wallboardfabrik (Norway), and Olin Industries before joining Masonite, where he is now Manager of Research.

Fig. 1.—Cylinder of wood restrained by thick ring of steel. Strain gages are mounted on the ring.

Steel Clamps: Steel rings ½ inch high were made with the following dimensions: I–outside diameter, 1.082 inch; wall thickness, 0.0405 inch. II–O.D., 1.201 inch; thickness, 0.101 inch. III–O.D., 1.502 inch; thickness, 0.251 inch. IV–O.D., 1.275 inch; thickness, 0.375 inch.

Fitting Wood into Ring: The laminates were turned down to within 10 mils of the inner ring diameter, with the grain running parallel to the axis. After they were reconditioned at 30 per cent relative humidity, they were turned down to within 3 mils of the ring diameter. One end of the cylinder was slightly beveled and the cylinder was press-rammed into the ring so that the entering end was flush with the face of the ring. The protruding end of the cylinder was turned down, so that the new end was flush with the second face of the ring. Table 1 records some pertinent information.

Measurement of Swelling Stress: The assembly is analogous to a thick-walled cylinder that is subjected to an internal pressure—the internal pressure being the swelling pressure of wood. According to Timoshenko,[4] the tangential stress at a point in the wall r distance from the center is a tensile stress given by:

$$\sigma_t = \frac{a^2 p_i}{b^2 - a^2}\left(1 + \frac{b^2}{r^2}\right) \quad (3)$$

where a is the inner radius of the ring, b is the outer radius, and p_i is the internal pressure (or swelling pressure). At the outer surface r equals b, and:

$$\sigma_t = \frac{2a^2 p_i}{b^2 - a^2} \quad (4)$$

Since $\sigma_t = Ee_t$
where E is Young's modulus for steel and e_t is the tangential strain at the outer surface,

$$p_i = \frac{(b^2 - a^2)\, Ee_t}{2a^2} \quad (5)$$

Thus if e_t is determined, p_i can be calculated. The e_t value was measured with a conventional SR–4 resistance strain gage mounted tangentially on the steel ring (Fig. 1). Two strain gages are shown mounted on the ring. Actually, one was used. An empty ring with its strain gage served as a standard for temperature compensation.

Method of Exposing End Grain to 100 Per cent Relative Humidity: The open end of a copper cup 1–¼ inches in diameter was set over each face of the ring and sealed to it with rosin-beeswax. Sealed to the cup was a tube that led to a water reservoir (a test tube). In this manner, both ring faces were exposed to 100 per cent relative humidity. (See Fig. 2.) The entire assembly was kept at 80° F.

Method of Measurement: After the copper cups were attached, the entire assembly (without water reservoir) was kept in a room at 30 per cent relative humidity for a month. Strain readings were then constant and the zero readings were established. (Some pressure probably existed here due to the force-fit.) The water reservoirs were then attached and measurements were made at convenient intervals.

Equilibrium was reached between 40 and 200 days. After equilibration, the copper cups were removed and the length of the wood cylinder was immediately measured and compared with the original length. The biggest increase over the original length was 0.001 inch. Thus no significant extrusion had occurred.

Fig. 3 describes the internal pressure as a function of time for wood with specific gravities of 0.69 and 0.83. Duplicate curves are given for each gravity class. Consider the curves for the lower gravity class. In both, the internal pressure rose to a maximum and then dropped off rapidly with time. Since the initial moisture content was 3 to 5 per cent, the wood was relatively nonplastic and was able to sustain appreciable stresses. With time, the moisture content increased, the plasticity also increased, and the wood was unable to sustain the swelling stress. Internal swelling (buckling) into the lumen occurred.

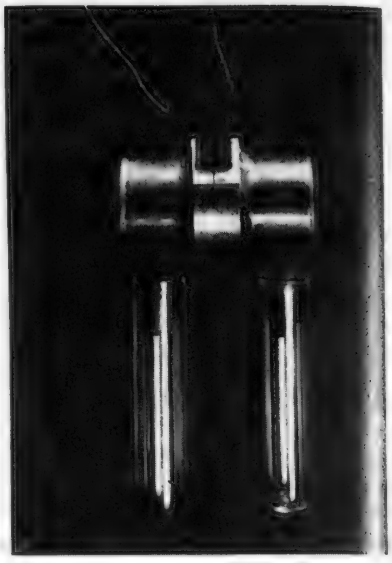


Fig. 2.—Complete assembly for restraining the swelling of wood while it is exposed to 100 per cent relative humidity.

The maximum value shown in the curve does not represent a true swelling pressure since swelling was not completely restrained. The maxima represent some yield stress in compression. The two maxima for presumably similar specimens are appreciably different (930 and 180 pounds per square inch). Suppose that, after the specimens were turned down on the lathe, the specimen responsible for the lower curve was one-half mil larger in diameter than that of the other specimen. When the specimens were inserted into the rings, a greater compressive load would act on the dry cylinder in the former case. This action is in the same direction as that of the corresponding reaction due to swelling; consequently when it is exposed to water vapor, a smaller measured internal pressure would be sufficient to cause plastic failure. Because of the initial compressive stress within the ring, a negative strain would be observed after the plastic fails. This accounts for the apparently negative internal pressure. The higher of the two values is therefore closer to the actual internal pressure. Internal swelling did occur as shown by the fact that, when the specimens were reconditioned to

Table 1.—RING AND WOOD DENSITY DATA

No.	Specific gravity of wood	Ring dimensions		Diameter of cylinder of wood In.
		Outside diameter In.	Wall thickness In.	
1	0.685	1.080	0.041	0.998
2	.686	1.201	.101	.999
3	.828	1.080	.041	.998
4	.824	1.201	.101	.999
5	1.17	1.201	.101	.999
6	1.17	1.502	.250	1.000
7	1.25	1.201	.101	.999
8	1.24	1.502	.250	1.000
9	1.34	1.502	.250	1.000
10	1.34	1.752	.375	1.002
11	1.41	1.502	.250	1.000
12	1.42	1.752	.375	1.002

[4] Timoshenko, S. Theory of elasticity. McGraw Hill, New York, N. Y. Second edition, 1951.

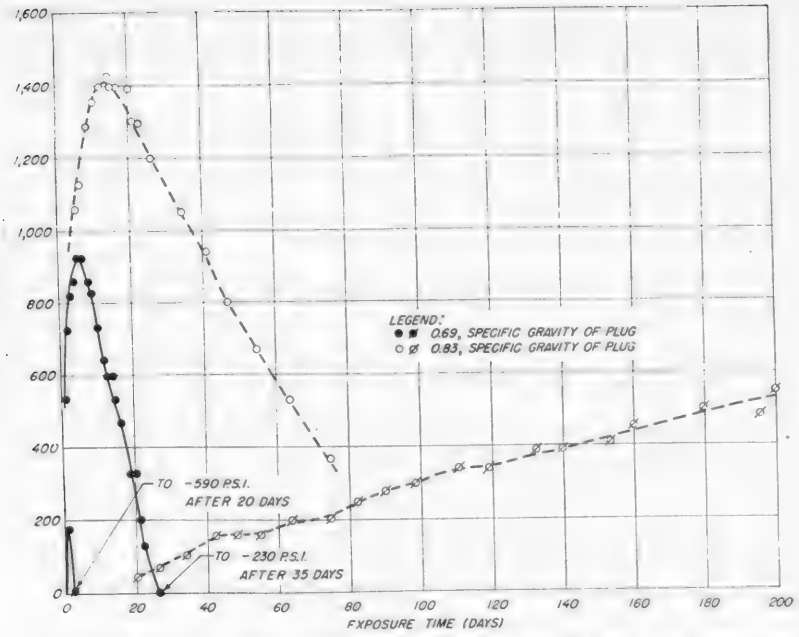


Fig. 3.—Internal pressure that develops when wood equilibrated at 30 per cent relative humidity is exposed, under swelling restraint, to 100 per cent relative humidity.

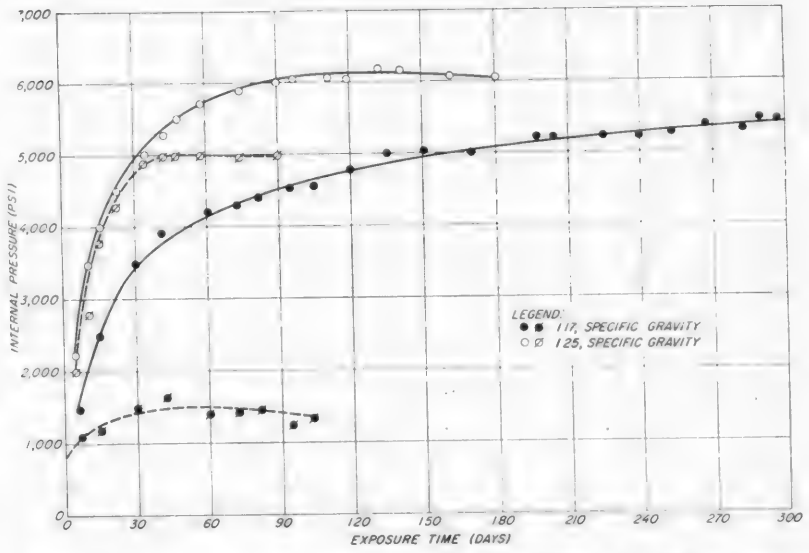


Fig. 4.—Internal pressure that develops when wood equilibrated at 30 per cent relative humidity is exposed, under swelling restraint, to 100 per cent relative humidity.

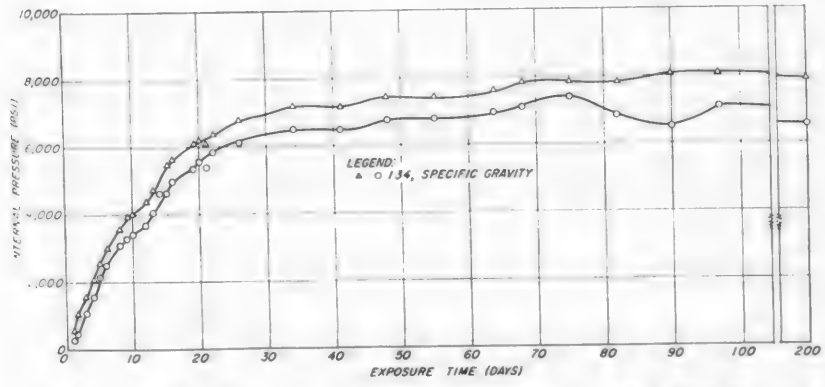


Fig. 5.—Internal pressure that develops when wood at a specific gravity of 1.34 is equilibrated at 30 per cent relative humidity and then exposed under swelling restraint to 100 per cent relative humidity.

30 per cent relative humidity, they dropped out of the rings.

Consider now, in Fig. 3, the two curves for wood of specific gravity, 0.83. One of them reached a maximum of over 1,400 pounds per square inch before plastic failure occurred. The second curve was still rising slowly after 220 days. It had reached a pressure then of only 600 pounds per square inch.

Fig. 4 describes the behavior of wood with specific gravities of 1.17 and 1.25. Again, each is given in duplicate. There is no indication of precipitous plastic failure as before. Internal swelling into the lumen, however, still can occur. (The void volume of these specimens is about 22 per cent and 17 per cent, respectively.) The internal pressure with the lower specific gravity specimens is 1,500 (No. 6 in table I) and 5,500 (No. 5) pounds per square inch. Again, the difference between the duplicates is believed to be due to differences in initial fit of cylinder in the ring. The internal pressure with the higher specific gravity specimens is 5,000 (No. 8) and 6,000 (No. 7) pounds per square inch. Here too, there is no indication of sudden plastic failure, but since the wood initially had a void volume of 17 per cent, the values are not true swelling pressures.

Fig. 5 pertains to specimens with a specific gravity of 1.34. Again, the two values, 7,000 (No. 10) and 8,000 (No. 9) are in reasonable agreement. The void volume of the wood was 11 per cent; thus some internal swelling could have occurred.

Fig. 6 pertains to specimens with specific gravity of 1.42. The values for the internal pressure are 9,500 and 10,000 pounds per square inch. The void volume was only 5 per cent. Although very little internal swelling could have occurred, there was still some question of identifying the internal pressure with the true swelling pressure.

A plug of densified wood (specific gravity 1.41) was prepared and turned down to a cylinder 1.13 inches in diameter. The cylinder at 160° C. was pressed through a die that tapered from 1.136 to 1.100 inches (see Fig. 7). A satisfactory section was obtained that had a moisture content of 4.6 per cent and a specific gravity of 1.44 (30 per cent relative humidity). The void volume here is about 4 per cent. Three test assemblies were made with this densified wood and rings with the following dimensions:

(1) Outside diameter, 1–1/2 inches; inside diameter, 1 inch.
(2) Outside diameter, 2 inches; inside diameter, 3/4 inch.

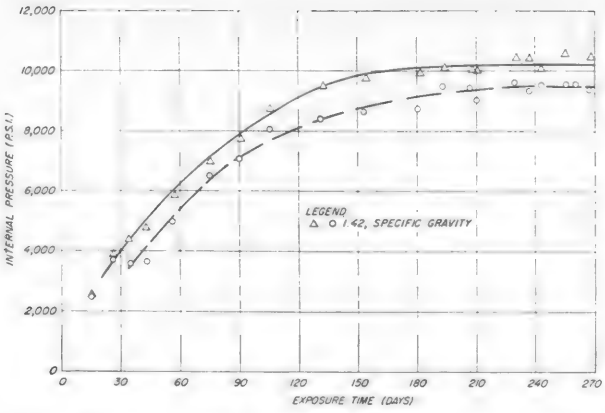


Fig. 6.—Internal swelling pressure that develops when wood at a specific gravity of 1.42 is equilibrated at 30 per cent relative humidity and then exposed under swelling restraint to 100 per cent relative humidity.

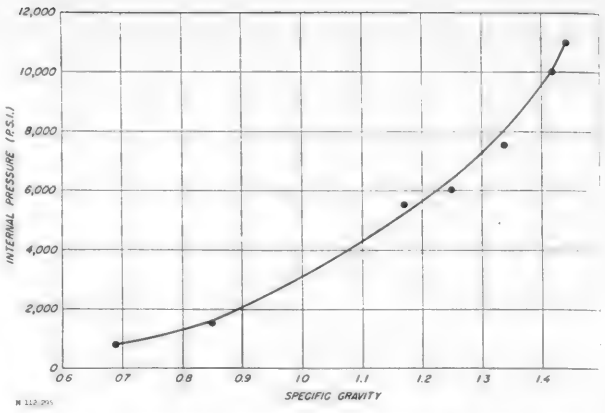


Fig. 8. — Relationship between specific gravity of wood and the apparent swelling pressure of wood between 30 and 100 per cent relative humidity.

(3) Outside diameter, 1–¾ inches; inside diameter, 1 inch.

Swelling equilibrium was reached in about five months and remained constant for the next three months, after which the work was discontinued. The copper cups were then removed and the cylinder heights measured at several places. The greatest increase in longitudinal dimension was 0.0015 inch. The apparent swelling pressures for the three specimens were 6,200, 10,000, and 11,000 pounds per square inch, respectively. Discarding the lower of the three values, it is seen that little was gained by a slight increase in specific gravity of the specimen (from 1.42 to 1.44).

Discussion

The maximum observed internal pressure for each gravity class is plotted against the specific gravity in Fig. 8. The internal pressure rises very rapidly with specific gravity; in the region covered by the experimental data, the pressure rises with the cube of the specific gravity. Although the remaining void volume at a specific gravity of 1.44 is only 4 per cent, extrapolation of the curve to a specific gravity of 1.50 (wood substance) is uncertain because of the steep rate of climb of internal pressure.

Fig. 7.—Cylinder and ram for preparing highly densified wood.

It was stated previously that the true swelling pressure is measured only under essentially complete swelling restraint. It will be noted that within each of the specific gravity classes—1.25, 1.34, 1.42, and 1.44—the maximum apparent swelling pressures were approximately constant, even though the two specimens in each class were tested with rings of differing wall thicknesses (table 1). The volume of the wood cylinder was about 6.4 cubic centimeters. At a specific gravity of 1.42, the weight was 9.1 grams. Under no restraint, the plug would swell roughly two cubic centimeters between 30 and 100 per cent relative humidity. With restraint due to a wall thickness of 0.25 inch, the outward swelling was approximately 0.01 cubic centimeter, whereas, with a restraint due to a wall thickness of 0.38 inch, the ouward swelling was very slighly smaller. (This is based on calculation of the tangential strain at the inner surface of the ring.) Although there was a very slight decrease in outward swelling for a ring with a greater wall thickness, there was no appreciable difference in apparent swelling pressure. Therefore, had the wall thickness been greater than 0.38 inch, it is doubtful whether a much higher apparent swelling pressure would have been observed.

The determination of the apparent swelling pressure is based on the measurement of the tangential stress at the outer surface of the steel ring. Actually, a gradient of increasing stress exists within the wall of the ring, with the tangential stress being greatest at the inner surface. From equation (3) the maximum tangential stress is given by

$$(\sigma_t)_{max} = \frac{p_i(a^2 + b^2)}{b^2 - a^2} \qquad (6$$

Using the data for specimen No. 1 (Table 1), which developed an internal pressure of 10,000 pounds per square inch, the value for $(\sigma_t)_{max}$ was found to be 20,000 pounds per square inch. The proportional limit for steel is reported to be above 30,000 pounds per square inch. Thus no zone within the wall of the ring was stressed beyond the elastic limit.

The maximum internal pressures for specimens of the different gravity classes are not true swelling pressures, since in no case was internal swelling completely restrained. Obviously, the closer the specific gravity of the specimen approaches that of wood substance (about 1.50) the better does the measured internal pressure approximate the true swelling pressure of wood substance. It is believed, however, that the true swelling pressure of wood substance between 30 and 100 per cent relative humidity is probably not much greater than 11,000 pounds per square inch.

Equation (2) is a theoretical relationship between p_e and p_o and f. Assuming f is 1 and $\overline{V}$ is the normal molar volume of water (18 milliliters), $P_e = 25{,}000$ pounds per square inch. Although this is about 2–1 times higher than the highest observed swelling pressure, the agreement is good considering the numerous assumptions implied in equation (1). For example, f very likely is greater than unity, and furthermore, the requirement of complete swelling restraint was not achieved.

Equation (2) shows that the true swelling pressure depends only on the initial and final relative humidities. In the extreme case where both are the same, the swelling pressure is obviously zero. The true swelling pressure of wood substance is independent of the species from which the substance is derived. The apparent swelling pressure of natural wood, however, is markedly dependent on the species, since the apparent pressure is determined by the ability of the natural wood to withstand compressive stresses without internal buckling. Obviously, the more dense the wood, the higher the compressive property and therefore the higher the apparent swelling pressure. The appropriate compressive property is some yield strength at a moisture content whose value cannot be stated, since it would depend on the specimen's specific gravity and the rate of diffusion of moisture into the wood. The high values observed for the apparent swelling pressure of wood account for the defects often observed following adsorption or desorption of moisture under conditions of partial restraint.

A Method for Dimensional Stabilization of Wood and Wood Veneer[1]

W. P. ERICKS

Vice-President, The Upson Co., Lockport, New York

Dimensional stabilizers for cellulose consist of a series of hydrocarbon compounds containing at least two hydroxyl groups attached to two different carbon atoms in a molecule. Experimental work indicated greatest efficiency when the hydroxyl groups were located at a distance of at least eight carbon atoms in a straight-chain molecule, approximately the distance between two primary alcoholic groups attached to two of the alternate anhydro-glucose rings of the cellulose molecule. It is suggested that maximum stabilization is obtained when these primary alcoholic groups are bridged, thus increasing the cross section of the cellulose molecule and permitting the process of sorption to proceed with greatly improved resistance to changes in the dimensions of wood.

THE NEW PROCESS for dimensional stabilization of cellulose was not the immediate concern at the time it was discovered. Efforts at that time were directed toward finding a satisfactory coating for an experimental fiber board impregnated with Vinsol, a highly colored, solvent-extracted fraction of natural wood rosin capable of bleeding into and discoloring practically any organic solvent-type coating.

In view of these circumstances, the water-soluble urea formaldehyde resin was used in experimental preparation of coatings. Although the resin film obtained from water-soluble urea formaldehyde resin was not discolored by Vinsol, its inherent brittleness precluded its successful use for the purpose at hand. It became apparent that the resin film had to be plasticized.

It was reasoned that, in order to be compatible with a water-soluble urea formaldehyde resin, a plasticizer should be initially soluble in water. Subsequently, it should lend itself to conversion into an insoluble compound by heat treatment, which was required anyway for curing of the resin film. It was then supposed that some water-soluble polyethylene glycol dicarboxylic acid monoester could be prepared and dissolved in an aqueous solution of urea formaldehyde resin. Such a solution would then be capable of forming a non-brittle resin film. It was hoped that during the heating and curing of the resin film the monoester contained therein would undergo polymerization and thus form a water-insoluble alkyd-type plasticizer. The experimental work that followed indicated that a non-brittle film could be prepared from a mixture of urea formaldehyde resin and monoester, both dissolved in water. It was rather disappointing to learn, however, that the polymerization of the monoester took place at a much slower rate than that of heat curing of urea formaldehyde resin.

Discovery of Dimensional Stabilization

In the course of evaluating the plasticizing effect produced by polyethylene glycol dicarboxylic acid monoester on a film obtained from water-soluble urea formaldehyde resin, sheets of paper were coated with aqueous solutions containing both compounds in various proportions. The coated sheets of paper were dried, heated, and flexed to determine the degree of plasticization obtained. Some sheets of low caliber paper without a surface size were wetted so readily by the solution that it penetrated on the opposite side. After they were dried, these sheets of paper showed a remarkable resistance to curling and cupping when either wetted with water or when subjected to variation of humidity in the atmosphere. Further study of this startling property revealed the following:

1. The sheets of paper impregnated with a solution of urea formaldehyde resin containing a monoester lost a considerable portion of their ability to contract and expand during their sorption process.

2. It was the monoester to a major degree, and the urea formaldehyde resin to only a minor degree, that produced the dimensional stabilization of the paper sheets.

3. The greatest degree of dimensional stabilization of paper sheets with a given monoester solution was obtained when the paper sheet was impregnated throughout its whole mass, and not by merely coating its surface.

A study of the chemical composition of these stabilizers revealed that all their molecules have two or more hydroxyl groups. It is believed that the identity of these groups with hydroxyl groups present in the cellulose molecules is responsible for the attraction existing between the two types of compounds. No complete

[1] Presented at the Fall Meeting of the Northeast Section, FPRS, held Oct. 31–Nov. 1, 1957, in New York, N. Y.

The Author: W. P. Ericks graduated in chemical engineering from Pratt Institute, and received MA and PhD degrees in chemistry from the University of Buffalo. He was then associated with Charles Pfizer & Co., National Aniline Division of Allied Chemical & Dye, and American Cynamid Co. before joining Upson as director of research in 1942. Ericks holds some 30 U. S. patents.

and exact explanation of the mechanism for the dimensional stabilization of cellulose is available. It is suggested, however, that the improved dimensional stability produced in cellulose is the result of orientation of stabilizer molecules parallel to the axis of cellulose molecules. The union that takes place between the two types of compounds may occur by hydrogen and/or by true chemical bonding. In accordance with the accepted spatial configuration of the cellulose molecule, its primary alcoholic groups extend farther away from the axis than do the secondary alcoholic groups. The bridging of primary alcoholic groups will be facilitated when the hydroxyl groups in the stabilizer molecule are located at either the same or somewhat greater distance than the distance between the primary alcoholic groups located on the alternate anhydroglucose rings of the cellulose. According to the literature, such distance is equal to 10.3Å,[2] and the distance between two carbon atoms is equal to 1.54Å.[3]

When the above data are considered, it becomes apparent that an eight carbon atom chain will be able to fit into the distance of 10.3Å. Experimental data showed that most effective stabilizers actually have at least eight carbon atoms in the chain, with a hydroxyl group attached to each of the terminating carbon atoms. It is believed that molecules of the stabilizers containing hydroxyl groups attached to carbon atoms spaced apart at a distance greater than the eight carbon atom chain undergo bending in order to accommodate themselves into the available space between two primary alcoholic groups attached to the alternate anhydro-glucose rings in the cellulose molecule. In this position, the dimensional stabilizer produces a permanent increase in the cross section of the molecule and thus permits the processes of desorption and adsorption to take place without altering the cross-sectional dimensions of the cellulose molecule.

Stabilizers composed of molecules in which the hydroxyl groups are located at distances shorter than 10.3Å. will not be able to reach out from one to another of the primary alcoholic groups located on the alternate anhydro-glucose rings of cellulose. Such stabilizers may then attach themselves to alcoholic groups in closer proximity to the axis of the cellulose molecule. The cross section of the molecule will then be increased to a minor degree, and the ensuing dimensional stabilization will be smaller than in the case first described. This consideration was borne out by actual experiments, which showed that dimensional stabilizers with hydroxyl groups attached to the carbon atoms lying at a distance of less than 10.3Å are less effective than those possessing eight or more carbon atoms in the chain with hydroxyl groups attached at each end of the molecule. It is not intended to exclude the possibility that bridging of accessible hydroxyl groups located on different molecules may take place concurrently with the one suggested above.

[2] Ott, Emil. 1946 High Polymers; Vol V; p. 209–210 Interscience Publishers Inc., New York, N. Y.
[3] Ibid.

Process for Dimensional Stabilization

Further work showed that, depending on the kind and the quantity of the monoester introduced into the paper, its dimensional changes under varying humidity conditions in the atmosphere can be either reduced or substantially eliminated. In fact, not only the dimensions of felted cellulose fiber sheets could be stabilized, but other materials composed predominantly of cellulose, such as cotton and linen fabrics and wood veneer, could be stabilized either partially or almost entirely against contraction and expansion that normally takes place during the sorption process.

Ordinarily, the process of treating the paper with monoester solutions does not require the use of equipment other than that which usually is employed in paper mills. The process does not require prolonged soaking of paper nor use of high temperatures and pressures. A thorough impregnation of a sheet of paper can be accomplished by wetting the paper surfaces with a monoester solution, wet packing the paper for several hours, and then drying it by any conventional method. The monoester possesses surface-active properties and thus it accelerates the penetration of solution into the paper sheet during its wet packing.

In the event the strength characteristics of the cellulose material have to be retained or improved, the monoesters are then used in combination with water-soluble thermosetting resins, such as urea-, phenol-, and melamine-formaldehyde types. Besides restoring and at times even improving the strength of the cellulose product treated with the monoester, the incorporation of thermosetting resins into it produces a thorough fixation of the monoesters in and on the cellulose fibers. It is believed that the thermosetting resins envelop the monoester and, after setting, prevent attack by solvents.

Numerous examples of monoesters as dimensional stabilizers for cellulose are given in an Upson patent and its reissue.[4] In this literature, other partial esters of polyhydric alcohols and polycarboxylic acids are also described. Soon after this discovery, it was learned that not only the partial ester, but each of its reactant components is also an effective stabilizer for cellulose materials.[5] The work was extended to hydroxy carboxylic acids, which also proved to possess the ability to dimensionally stabilize cellulose.[6]

At the present time, some of these dimensional stabilizers for cellulose are manufactured on a commercial scale and are available under the trade name of Stab-U-cels.

Before presenting experimental data on dimensional stabilization of wood, it should be explained that the reported hygroexpansivity along the *Z* axis represents the dimensional changes in the width of the board perpendicular to the predominating direction of fibers; the *X* axis relates to the length of the board parallel to the predominating fiber direction; while the *Y* axis is the direction perpendicular to the plane of *XZ* axis and represents the thickness of the board. Inasmuch as the dimensional changes occuring along the predominating direction of fibers are small, the hygroexpansivity along the *X*-axis is not reported herein. The hygroexpansivity removed along the other two axes are given in examples reported below.

Samples of pine wood measuring 1.5 by 11.75 by 0.25 inches and cut with the long dimension, in one instance, parallel and, in another instance, perpendicular to the grain direction, were soaked for 15 days in a 30 per cent solution of Stab-U-cel #1. The samples were subsequently ovendried for 2 hours at 225° F., measured, and then conditioned at 90 per cent relative humidity for 29 days when the measurements were repeated. The percent hygroexpansivity removed was determined by comparing the dimensional changes of impregnated pine wood to that of an untreated sample exposed to identical conditions of drying and conditioning.

The evaluation of the impregnated pine wood showed that it contained 24 per cent of Stab-U-cel, and that 64 per cent of the hygroexpansivity was removed along the *Z* axis and per cent along the *Y* axis.

[4] Ericks, W. P. U.S. Patent 2,629,701 and Reissue 23,866.
[5] Ericks, W. P. U.S. Patent 2,629,648 and U. S. Patent 2,629,674.
[6] Ericks, W. P. U.S. Patent 2,692,183.

Editor's Note: Persons interested in obtaining a more detailed description of the dimensional stabilizers identified in this paper by the trade names Stab-U-cel ♯1, ♯2N, ♯2GM, ♯5N, and ♯5M may find further information in the patents listed in footnotes 3, 4, and 5, or by contacting the Upson Chemical Corp. directly.

In another example, a white pine board measuring 12 by 12 by 0.25 inches was kept immersed in a 30 per cent aqueous solution of Stab-U-cel ♯2N for 3 days at room temperature. After oven drying it at 225° F. for two hours, it was conditioned in the humidity cabinet at 90 per cent relative humidity. The impregnated board contained 17 per cent of Stab-U-cel ♯2N, and lost 65 per cent of its normal hygroexpansivity along the *Z* axis and 80 per cent along the *Y* axis.

When Stab-U-cel ♯2GM was evaluated in like manner, it was found that the impregnated board contained 25 per cent of the stabilizer, and that 77 per cent of the hygroexpansivity was removed along the *Z* axis and 85 per cent along the *Y* axis.

Thus it may be summarized that white pine, a species of softwood, containing from 17 to 25 per cent of three different kinds of Stab-U-cels lost 64 to 77 per cent of its normal hygroexpansivity along the *Z* axis and 84 to 88 per cent of same along the *Y* axis.

The three samples of Stab-U-cels in Table 1 and those mentioned below belong to the general class of chemical compounds earlier described herein. The molecules of these compounds are of varying length, each containing at least two hydroxyl groups separated by a hydrocarbon chain of not less than six and not more than 14 carbon atoms.

Inasmuch as it was expected that impregnation of hardwood would present increased problems due to its greater density than softwood, the vacuum pressure technique employed from the outset.

Samples of Honduras mahogany wood veneer used in the experimental work were of various dimensions. Before impregnation, most of them measured approximately 15.5 inches in width, 52 inches in length, and 0.062 inch in thickness when conditioned at 50 per cent relative humidity at 70° F. The samples were placed in the autoclave on stainless steel frame bars, separated by a distance of 1.5 inches from each other. After the cover was bolted on, the autoclave was evacuated to 28–29 inches guage pressure to remove occluded air and water-vapor from the veneer. The veneer samples were subjected thereafter to reduced pressure for 10 minutes. Then the Stab-U-cel solution was sucked into the autoclave in such quantity that it completely covered the samples. The pressure in the autoclave was subsequently equalized with that of the atmosphere, and then increased to 70 pounds per square inch. The samples were allowed to remain immersed in the impregnating solution under this pressure overnight.

In the morning, the solution was discharged from the autoclave and the pressure was released. The samples were removed from the autoclave and the excess of impregnating solution remaining on the surfaces of the samples was wiped off. The impregnated samples were dried at 70° F. and 50 per cent relative humidity to a constant weight.

Two-inch-wide strips were then cut from the veneer samples with the long dimension of approximately 16.5 inches perpendicular to the predominating direction of the fibers. These strips were dried at 225° F. to a constant weight for approximately 30 minutes and, after being weighed and measured, were conditioned in a cabinet at a relative humidity of 90 per cent at 70° F. at which time they were measured. The dimensional changes of the above strips were compared to those of the original veneer sample subjected to conditions identical to those just mentioned.

The results of the experiments are given in Table 2. The measurements along the *Y* axis were unreliable because the veneer was too thin, and therefore they are not reported.

In summary, the results indicated that 45 to 70 per cent of the hygroexpansivity of Honduras mahogany wood veneer, representing a species of hardwood, could be removed along the *Y* axis when the impregnated samples contained from 23 to 36 per cent of one of the three kinds of dimensional stabilizer employed.

The initial work with wood, as reported above, indicates that a substantial portion of its hygroexpansivity can be removed by impregnation with Stab-U-cel. Much work remains to be done to determine the maximum efficiency of the process.

It should be noted that unsuccessful attempts have been made in the past to stop the process of sorption and the ensuing hygroexpansivity of wood by coating it with a continuous water-impermeable film. It was found that, even under the best conditions, this process did not eliminate but merely retarded the hygroexpansivity of wood.

Table 1.—PERCENTAGE REDUCTION OF HYGROEXPANSIVITY IN PINE WOOD

Per cent and kind of Stab-U-cel in solution	Stab-U-cel in pine wood, %	Hygroexpansivity removed along the Z-axis, %	Hygroexpansivity removed along the Y-axis, %
30% Stab-U-cel #1	24	64	84
30% Stab-U-cel #2N	17	65	80
30% Stab-U-cel #2GM	25	77	85

Table 2.—PERCENTAGE REDUCTION OF HYGROEXPANSIVITY IN HONDURAS MAHOGANY WOOD VENEER

Per cent and kind of Stab-U-cel in solution	Stab-U-cel in th veneer, %	Hygroexpansivity removed along the Z-axis,%
30% Stab-U-cel #1	29	45
30% Stab-U-cel #5N	28	70
20% Stab-U-cel #5M	23	51
25% Stab-U-cel #5M	27	52
35% Stab-U-cel #5M	36	61

High-Temperature Kiln-Drying of Lumber—A Summary of Canadian Progress[1]

W. W. CALVERT

Ottawa Laboratory, Forest Products Laboratories of Canada,[2] Ottawa, Ontario

Both hardwoods and softwoods have been dried in an experimental high-temperature kiln of semi-commercial size. Softwoods could be dried very quickly with little degrade, while low-grade hardwoods were affected more seriously. Clear hardwoods dried more satisfactorily. Wood dried at high temperature became considerably less hydroscopic than conventionally dried material.

THE KILN-DRYING OF LUMBER at high temperatures—that is, at temperatures above the boiling point of water—has received much attention during the past four or five years. That lumber could be dried in a matter of hours rather than days was, of course, a most attractive proposition, and it was not unusual to find many kiln manufacturers, mainly foreign, capitalizing on this favorable prospect.

The idea of using temperatures above the boiling point of water, after many years of inactivity, was revived in Germany following the Second World War, and kiln manufacturers in that country laid claim to drying lumber satisfactorily with these new high-speed drying techniques. Agencies for these manufacturers were soon established in Canada, and a number of high-temperature kilns made their appearance in Montreal and Toronto. As these units were installed and interest in them increased, numerous inquiries were received by the Forest Products Laboratories of Canada, and it became apparent that technical data applicable to Canadian conditions were needed. It also seemed, at the time, that certain claims made by various kiln manufacturers were unfounded or, at best, were based on insufficient factual experience.

Studies on the drying of lumber at high temperatures have been in progress at the Ottawa Laboratory since 1952. Research has been directed towards assessing the practicability of drying commercial timbers by this method, and to secure basic data on the factors involved in the high-temperature seasoning process.

The Process

A distinction should be drawn between the two processes commonly referred to as "high-temperature" drying, or, more misleadingly, "super-heated steam" drying.

In one process, wood is dried in steam or super-heated steam, which occupies the kiln to the complete exclusion of air. In the other, a mixture of air and steam is used. The distinction is an important one, for not only is the drying process of a different nature but the means of control are, of necessity, through different media.

Briefly, a super-heated steam kiln is one into which super-heated steam is being continuously injected, or one which is of the nature of a retort—completely sealed except for a single outlet, which acts as a safety valve. Super-heated steam is steam heated over and above the boiling point of water. This means that it can give up some of its heat without condensing. This super-heat can be used as a heating agent and, thus, as a drying agent. Because there is no air present, relative humidity relationships are not applicable and the degree of super-heat or the dry-bulb temperature is the only controlling factor, when given the high circulation rate necessary (1, 2, 3)[3].

The other process included under the *generic* term of "high-temperature drying" uses air-steam mixtures. Fresh air is brought into the kiln in the conventional manner, but any steam present, apart from that injected for deliberate humidification purposes, is produced from the moisture expelled from the lumber; it is a resultant of the drying and not a prerequisite to the process. It has been established that there is a relationship between relative humidity and equilibrium moisture content at temperatures above the boiling point and, therefore, control of this process is through the medium of wet- and dry-bulb thermometers, as in a kiln with conventional temperatures.

The Kiln

In 1952, the Ottawa Laboratory received, on loan, a high-temperature kiln of German manufacture for use in research. This kiln, of semi-commercial size, had a capacity of 500 ft.b.m. of one-inch lumber. Most of the exploratory investigations on softwoods were conducted in this kiln. It became apparent, however, as is later explained, that the unit was not an efficient research tool, although perhaps a satisfactory kiln for some commercial purposes.

It was decided, therefore, to construct a new kiln of similar size and capacity that would embody features necessary for research work but not necessarily found in conventional units. For example, access holes, sealed windows, and a variable-speed motor were included.

Investigations and Results

The procedures and results of these investigations have been reported in other publications (1–6). However, a brief summary of these studies and a discussion of some of the problems encountered will be presented here.

Exploratory investigations showed that softwood lumber could be dried at high temperatures in a remarkably short time and with little degrade. Table 1 shows examples of the drying schedules on both eastern and western softwood species. A typical Drying Chart for a softwood charge is shown in Fig. 1.

The major defect noticeable was severe case-hardening, which was easily relieved by a conditioning period. Discoloration was slight and general

[1] Presented at the Fall Meeting of the Northeast Section, FPRS, held October 31–November 1, 1957, in New York City.

[2] A division of the Forestry Branch, Department of Northern Affairs and National Resources, Ottawa, Canada.

The Author: W. W. Calvert received BS and BSF degrees from Michigan State University in 1951 and 1952. He has been a forest products engineer at the Ottawa Laboratory since graduation.

[3] Numbers in parentheses refer to the Literature Cited at the end of this report.

Table 1.—RESULTS OF SELECTED RUNS ON EASTERN AND WESTERN SOFTWOOD SPECIES

Species—Thickness	in.	Average drying temp. °F.	Average moisture content		Warming up period Hrs.	Drying time Hrs.	Cooling period Hrs.	Total time Hrs.	Average drying rate % M.C./hr.
			Initial Per cent	Final Per cent					
E. w. spruce	1	230	39.4	7.8	3.25	11.50	4	18.75	2.5
E. w. spruce	1	232	51.9	5.6	2.75	13	4	19.75	3.5
E. w. spruce	2	234	60.2	[1]22.7	3.25	9	4	16.25	4.0
E. w. spruce	2	230	73.1	[1]18.6	3	27.25	4	34.25	2.0
E. w. pine	1	230	113.2	9.8	3	35.25	4	42.25	2.9
W. hemlock	1	237	75.2	5.2	2.50	25.50	4	32	2.8
W. hemlock	2	237	56.4	7.0	3	46	5	54	1.1
D. fir	1	235	47.3	8.2	4	17.50	6	27.50	2.2
D. fir	2	237	41.2	7.2	2.75	35	6	43.75	1.0
W. r. cedar	1	234	45.4	6.6	1.75	24.25	6	32	1.6
W. r. cedar	2	235	36.1	12.5	2.50	28.50	6	37	0.8

[1]These runs were discontinued because of mechanical breakdown.

w. s removed during surfacing. Power consumption figures for a number of r. s appear in Table 2.

The exploratory runs, carried out in the kiln of German manufacture, indicated considerable promise for the process. Under the conditions of study, however, a major shortcoming of the process was the high variation in final moisture content. After consideration of the possible causes of this lack of uniformity, it was tentatively concluded that such variations were not inherent to the process, but resulted from inadequate control. Thus, the kiln as a research tool came under scrutiny and the following disadvantages associated with the kiln were put forth as contributing either entirely or partially to poor uniformity:

1) Unidirectional circulation system (centrifugal fans rather than axial—or cross-shaft fans),
2) Meager control over humidity,
3) Temperature fluctuations,
4) Absence of recording apparatus,
5) Fixed motor and fan speed.

The new experimental kiln, designed and built at the Ottawa Laboratory (described in Appendix I), provided a means of testing and evaluating the above points as they might contribute to improving the process. Thus, preliminary runs, while providing a large volume of additional information on the drying characteristics of various species, were primarily designed to assess the drying characteristics of the kiln. These early runs in the new kiln showed, as before, that the quality of the lumber after drying was very satisfactory but, mainly, that uniformity in moisture content had been improved substantially. For example, from identical sampling systems covering the entire kiln charge, the standard deviation of the mean moisture content had been reduced from around four per cent to less than one per cent.

Two runs conducted with the circulation rate reversed periodically showed a definite effect on improving final moisture content uniformity. The

Table 2.—ELECTRICAL CONSUMPTION PER LB. OF WATER EVAPORATED IN HIGH TEMPERATURE DRYING

Kiln	Species	Stock	Kw. hr.	Equivalent lbs. of steam
German	E. w. spruce	2"	.44	1.55
German	E. w. spruce	2"	.75	2.65
German	E. w. spruce	1"	.61	2.17
German	E. w. pine	1"	.50	1.76
German	W. hemlock	1"	.49	1.72
German	W. hemlock	2"	.69	2.45
German	D. fir	1"	.54	1.86
German	D. fir	2"	.80	2.83
German	W. red cedar	1"	.70	2.48
German	W. red cedar	2"	1.09	3.86
German	Y. birch	1"	.66	2.34
German	Y. birch	1"	.59	2.07
German	Y. birch	1"	.45	1.59
German	Y. birch	1"	.44	1.55
New kiln	E. w. spruce	1"	.58	2.03
New kiln	E. w. spruce	1"	.63	2.24
New kiln	E. w. spruce	1"	.57	2.00
New kiln	E. w. spruce	1"	.65	2.30
New kiln	E. w. spruce	1"	.48	1.68
New kiln	E. w. spruce	1"	.58	2.06
New kiln	E. w. spruce	1"	.55	1.95
New kiln	E. w. spruce	1"	.60	2.11
New kiln	E. w. spruce	1"	.44	1.54

Consumption figures are for heaters only during the warming up and drying periods.

1 kw. hr. taken to be equivalent of 3.53 lbs. steam.

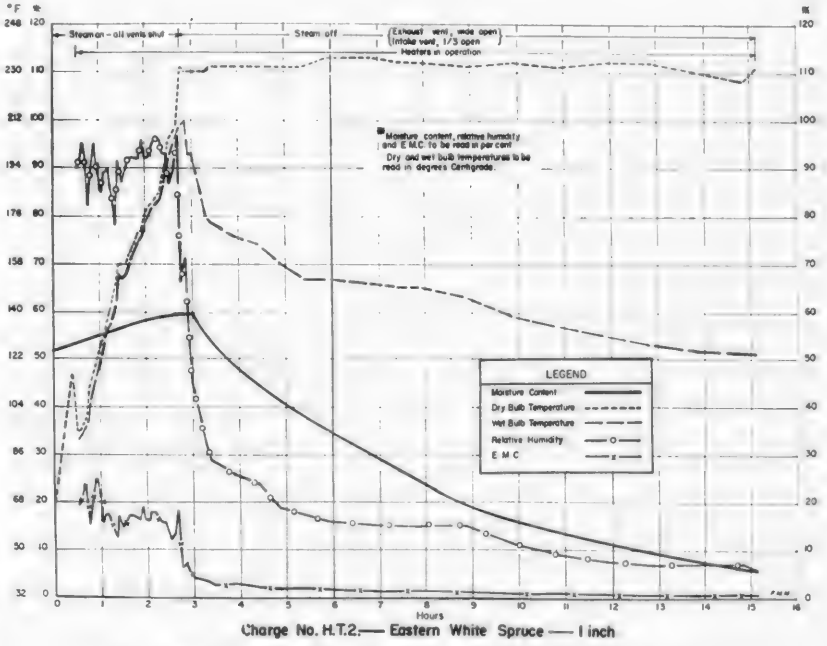


Fig. 1.—Results of Charge No. H.T.2.—one-inch eastern white spruce.

principal effect—not fully realized at the time—was that the rate of circulation had a highly significant effect on the degree of uniformity.

To investigate this problem further, a series of six runs on eastern spruce were carried out. Various combinations of circulation rates and reversed circulation were employed. These results, when analyzed, pointed significantly to the fact that both reversal of circulation and rate of circulation affect final uniformity.

Table 3 shows the conditions prevailing during each run and indicates, by means of a specific range, the improvements gained in final uniformity. While the range of final moisture content in kiln-dried lumber remains unspecified in most grading rules and adopted sets of standards, an indication of what is acceptable can be gained from various sources. In general, an average of 8 to 10 per cent moisture content is quoted for the better grades of kiln-dried, one-inch softwood lumber (4). Variation from this average may be of the following order:

90 per cent shall not exceed 12 per cent M.C.
10 per cent shall not exceed 15 per cent M.C.
average—10 per cent M. C.

The warming up of the kiln and charge took approximately 2½ hours in each case. Once the drying temperature was reached, conditions were maintained at the above temperatures throughout the run. All charges were conditioned for 1½ hours in the same manner. The drying rates quoted are from the 60 per cent level to the 10 per cent level of moisture content only, in each case. This allows for a direct comparison of the rates for the various runs.

In summary, these tests for one-inch eastern white spruce, dried at 240° F. and at a wet-bulb temperature of 200° F. and with a conditioning period as indicated above, have shown that:

1) The range of final moisture content is a function of circulation rate and reversal, or non-reversal of the circulating system;
2) The rate of circulation exercises a far greater influence on the final moisture content than does the periodic reversal of the circulation system;
3) To bring the range of final moisture content into limits acceptable to industry, a minimum circulation rate of 500 f.p.m. is necessary if relatively long conditioning periods are to be avoided;

Table 3.—MOISTURE CONTENT UNIFORMITY TESTS—SUMMARY OF RESULTS

Rate f.p.m.	Circulation Direction	Moisture content Initial %	Moisture content final %	Time kiln Hrs.	Drying rate, M.C. loss per hour, %	Range in final moisture content Per cent of boards in charge above final means plus 1%	2%	3%	4%	10%
900	Reversing	86.4	5.5	18¼	6.8	7	0	0	0	0
900	Non-reversing	86.3	5.0	19	6.8	13	3	3	3	0
600	Reversing	61.9	4.6	17½	5.1	12	5	2	0	0
600	Non-reversing	78.8	5.3	21½	4.0	8	5	3	3	0
400	Reversing	78.3	7.2	21½	3.8	18	13	10	7	3
400	Non-reversing	96.1	6.5	24	3.8	28	20	17	7	0

Note—Each charge was dried at: Dry-bulb temperature of 240°F. (115°C.)
Wet-bulb temperature of 200°F. (95°C.)
(Relative humidity 47 per cent; E.M.C. 3.9 per cent)

4) The use of very high circulation rates not only exercises a beneficial effect on final moisture content range but also substantially reduces the drying time.

It is reasonable to assume that a similar behavior will apply to other softwood species.

Further runs on softwoods were carried out both to establish schedules and to investigate further the kiln itself. The tests were uniformly successful from a schedule viewpoint, and eventually led to the publication of F.P.L. of C. Technical Note No. 2 "High-Temperature Kiln-Drying of Eastern Canadian Softwoods—Drying Guide and Tentative Schedules".

Hardwoods

With the conclusion of this basic work on softwoods, attention was turned to similar investigations on Canadian hardwoods. It should be remarked that four exploratory runs on yellow birch were carried out in the German kiln. Results of these initial runs were only moderately favorable as collapse and honeycombing were prevalent in all runs, while surface checking ranged from moderate to severe. However, this preliminary work indicated that, with closer control of conditions and very careful sampling methods, hardwoods could probably be dried green from the saw with satisfactory results.

Other researchers in Europe had found that green hardwoods did not respond well to high-temperature drying, and recommended that air-drying take place as a prior requisite. Thus, these early runs were not discouraging in that the process did appear to hold promise.

Because the greatest problem in drying hardwoods appeared to be the elimination or reduction of the severe stresses induced during drying, a brief study of the effect of steaming upon the stress-strain relationship was undertaken. Although inconclusive, the results of this work seemed to indicate that a periodic steaming might retard the incidence of collapse, honeycombing, and checking.

Following this, four complete runs at high temperatures were carried out on freshly sawn one-inch yellow birch. Three of the charges were dried at a dry-bulb temperature of 215° F., and another at 220° F. Each charge was brought up to temperature gradually at the highest humidity obtainable, which tends to reduce both collapse and surface checking, at least during the early stages. For comparison, an additional charge was dried according to a conventional schedule.

The results of these tests showed that, in general, the quality of the dried charges was remarkably good, particularly by comparison to the initial runs mentioned previously. In these latter runs, humidities were kept higher, temperatures somewhat lower, and an intermittent steaming period was used. The most prevalent defect again was collapse which, occurred mainly in heartwood boards and at the junction of heartwood and sapwood. Sapwood boards were entirely free of collapse. Surface checking occurred in some boards but was not severe, and was mainly evident in heartwood portions and in the pith. Honeycombing was absent. Although different steaming schedules were used in the four runs, very little difference in quality was noticeable between charges—certainly no steaming schedule could be recommended as superior. Steaming did appear to prevent honeycombing (which, as checking, results from the stresses set up). Steaming also served to bring final uniformity of moisture content to within more acceptable limits.

Practical Considerations

The foregoing has been a brief summary of investigations carried out at the Ottawa Laboratory. All have been reported in the following publications of the Laboratories which are available on request.

1. High-Temperature Kiln-Drying of Canadian Woods—Report of Exploratory Investigations—Softwoods. J. L. Ladell.
2. The Outlook for High-Temperature Seasoning in Canada. J. L. Ladell.

3. High-Temperature Drying of Lumber. J. L. Ladell.
4. High-Temperature Drying of Yellow Birch. J. L. Ladell.
5. High-Temperature Kiln-Drying of Eastern Canadian Softwoods—Drying Guide and Tentative Schedules. J. L. Ladell.

It may be pertinent to discuss the more practical aspects of high-temperature kiln-drying, as well as future work to be undertaken. When putting research work into practice, or on a practical level, problems are invariably encountered for which solutions cannot always be based on experimental work.

It can be generally stated that softwoods have been commercially dried with almost complete success by these methods, while hardwoods would appear to be a much trickier proposition. Nevertheless, one problem that did arise to some extent in the high-temperature drying of softwoods was the incidence of chemical brown stain in white pine. As this is a most valuable Canadian species, any factors contributing to its degrade are a serious matter.

The white pine used in the experiments had been dried green from the saw. As has been pointed out, stain did not occur to any appreciable extent. However, a number of additional high-temperature runs were conducted with the cooperation of a local firm, which supplied pine lumber from their own yard. And at a later date, this firm attempted a series of modified high-temperature charges within their own kilns. In each of these runs, chemical brown stain was prevalent to a severe degree—that is, the stain penetrated to a depth that could not be planed off. The lumber used in each of these runs was partially air-dried before it entered the kiln, and it is believed that this fact is the key to the occurrence of such stain. Because specific investigation into this problem is lacking, it has been tentatively recommended that, if possible, pine should be dried at high temperature green from the saw. If this is not feasible, extreme care should be observed. As can be seen in Table I, the drying time is very short, and the reduction in kiln time gained by air-drying is almost negligible.

Probably the most important of practical topics relating to drying is the cost structure of the process. The question of whether high-temperature seasoning has a cost advantage over other methods (and, if so, to what extent) is of vital concern to those contemplating the employment of these methods. Table 2 lists relative electrical power consumption for a number of runs and also provides theoretical equivalent steam requirements. At best, however, these are only indicative, and it is to be noted that economy was not a factor during these runs, particularly with respect to air venting. Moreover, as the Laboratory's kiln is not of commercial dimensions, these factors may not apply in a larger chamber. Finally, since electricity was used rather than steam, only theoretical equivalents can be given. Steam, if used, must be high pressure (around 75 lbs.). Data indicative of steam consumption in conventional kilns have been given by the Forest Products Laboratory, Madison, Wisconsin, as follows:

Softwoods = 1 inch, 2.01 to 2.75 lbs. steam per lb. water evaporated.

Birch = 1 inch, 2.50 to 4.00 lbs. steam per lb. water evaporated.

Apart from actual consumption figures, it is felt that a distinct advantage of this method lies in the quick turnover of lumber inventories possible under these conditions. A similar consideration is the space required by both the kiln and the lumber. For example, a kiln employing high temperature need only be a fraction the size of a conventional kiln to produce the same volume of seasoned lumber.

As previously mentioned, hardwoods were found to be somewhat more difficult to dry than softwood species. Although this is generally true, there are a number of points that should be kept in mind. Low-grade hardwood exhibited considerable degrade, while for the clear material this method showed great promise. Thus it may be that a high-temperature kiln for "blanks" and dimension stock could become a worthwhile proposition. Care would be necessary in preparing the lumber for drying. End-coating would be imperative, and sticker spacing would have to be reduced. With such precautions taken, it appears that even with low-grade stock any losses resulting from the severity of the schedules used would probably be more than offset by the economies from the much shorter drying time and the lower cost of drying.

It must be remembered also that the volume of experimental work carried out on hardwoods has not been nearly so extensive as that accomplished on softwoods. There is good reason to believe that further work will result in developing methods that will prove entirely successful for the high-temperature seasoning of both low-grade and clear hardwood stock. Work is planned by the Laboratory to investigate the stress-strain relationships as they specifically apply to hardwoods subjected to the conditions of high-temperature drying. It is thought that the key to success in this particular region lies in developing a schedule that combines the features of high-temperature drying with the natural resistances of the particular species to failure, with respect to the type and magnitude of stress, its duration, prevailing conditions, and the stage during drying at which stresses occur. In other words, a quantitative approach to this problem will be attempted in order to arrive at schedules for the various hardwood species.

Another point revealed during the Laboratory studies, and one which attracted considerable speculative interest, was that high-temperature-dried material became less hygroscopic than conventionally dried material. This was brought out rather incidentally during a conditioning period of strength specimens when it was noticed that, in a 12 per cent conditioning room, the average moisture content of the specimens did not exceed 11 per cent. This is markedly lower than might be expected. Empirical studies on Douglas-fir at the Vancouver Laboratory have shown similar results. Moreover, these results are supported by earlier observations at the Ottawa Laboratory and by those made elsewhere. It has been shown that high-temperature-dried material has lower E.M.C. values than conventionally dried material, and that this difference is increased at higher moisture contents (below the fiber saturation point), higher drying temperature, and humidity. It has also been shown that it is this reduction in E.M.C. that is largely responsible for an increased stability in lumber dried at high temperatures (5, 6).

In summary, it can be said that studies have indicated that high temperature drying appears to offer considerable possibilities for the kiln-drying of North American timber species. Considerable research remains to be done, however, before adequate and necessary data are available to permit the preparation of satisfactory drying schedules for all species.

Literature Cited

1. Stevens, W. C. 1952. Timber drying in superheated steam. Timber and Plywood. Sept.
2. Stevens, W. C. 1951. The seasoning of wood at temperatures above the boiling point of water. Wood (England) 6.
3. Keylworth, R. 1949. Grundlagen der Hochtemperaturtrocknung des Holzes (Fundamentals of high-temperature drying of wood). Holz-Zentralblatt, 75, 76. Sept.

4. Jenkins, J. H. 1954. Kiln-drying British Columbia lumber. Forest Products Laboratories of Canada, Ottawa, Bulletin, 111.

5. Pratt, G. H. 1955. High-temperature drying of African mahogany, Appendix I, D.S.I.R. Forest Products Research Laboratory, Princes Risborough, England.

6. Stamm, A. J., and others. 1955. Heat stabilized wood (Staybwood), Forest Products Laboratory, Madison.

APPENDIX I

Description of High-Temperature Kiln Constructed by Ottawa Laboratory, FPL of C

General: Overhead cross-shaft type, two fans mounted centrally, driven by single motor. "Transite" paneling over aluminum alloy framework. Interior coated with aluminum paint.

Insulation: 3-inch fiber-glass.

Capacity of Kiln: 500 ft.b.m. dimensions of pile as follows:

Length:	8 feet
Width:	3 feet
Height:	3 feet

Dimension of Kiln:

	Interior	*Exterior*	
Length	8'3"	9'1"	
Width	4'9"	5'5"	
Height	7'7"	8'3"	(10'6" overall)

Weight of Kiln: 3720 Lbs.

Performance: Temperature range: 60–300° F. (16–149° C.); Circulation rates: 350–1000 f.p.m. plus.

Heating and Humidification:

Heating: Electrical, controlled by the kiln controller-recorder through a pressure-switch that operates the main heater relay switch. Total wattage: 12 kilowatts, arranged in four banks of 3 kilowatts each. Banks mounted one on each side of each fan. Each bank consisting of three rows of six 275-volt elements, connected so as to operate off the 550-volt supply, giving a total of 1000 watts per row. Selector switches allow for the operation of one, two, or all three rows in each bank, producing an over-all 'low', 'medium', or 'high' heat as required.

Humidification: Low pressure steam (10 lbs.) through diaphragm valve, as in conventional kiln.

Fans: Two 24-inch Keith Blackman Reversible Streamlined type.

Rating of each fan at 70° F.

Volume	5000 c.f.m.
Pressure	1" S.P.
Max. operating temp.	300° F.
Speed	1500 r.p.m.
Fan load	2.51 H.P.
Recommended motor H.P.	3.0 H.P.

Fans reversible without loss in capacity. Operates in a 25 3/16" diameter orifice plate.

Shaft and Running Gear: Manufacturer and supplier as for fans. Hollow shafts in mild steel carried on double ball bearings with bearing distances of 6 ft. Cooling fans fitted at each end of the shaft between the kiln and bearings.

Motor: Schrage, A. C. Variable-speed Commutator motor, manufactured by the British Thompson-Houston Co. Ltd., and supplied by Canadian General Electric Co. Ltd.

Specifications: 550 volts, 3 phase, 60 cycles, 9 amps. H.P. 7/1.9/1.4, at R.P.M. 1850/500/370. Rating: continuous/continuous 30 min.—50° C.

Motor-speed Remote Control Gear: Supplied by Canadian Fairbanks-Morse Co. Ltd., consisting of 15 ft. of Stow ½-inch Flexible Shafting, with an 80-tooth, 5-in. Dia. gear wheel mounted on one end, and with the other leading into a remote station with a Dick terminal and a 5-in. dia. handwheel. The gear wheel engages a 20-tooth, 1¼ in. dia. gear wheel which replaces the controlling handwheel on the motor. Connections made at each end of the shaft with Stow Type 5.F. terminals.

Instrumentation: Dry-kiln Controller-recorder: Moore Dry Kiln Co. of Canada Ltd. Range 60–300 F., clockwork, two dry bulbs, one wet bulb. Kilowatt-Hour Meter: Type 5.3. Polyphase meter, Sangamo Co. Ltd. Kilowatt Meter: Type AD 6; 0–50 K.W.; Canadian General Electric Co. Platform Scales: 6000 lbs. capacity; Fairbanks-Morse Co., Ltd.

Discussion

Anon.: What effect does high temperature have on machinability? Does it cause brashness? So much so that machining degrade will result?

Mr. Calvert: No specific machining tests were carried out on the lumber dried by these methods, principally because our research program has not, to date, incorporated such studies and, consequently, we have no direct experience upon which to base comparisons. However, all lumber was used in our carpentry shop where a variety of products for our own use are manufactured. These items include cabinets, tables, benches and chairs, displays, etc., and have undergone the usual machining operations of planing, jointing, sanding, gluing, and finishing. We asked our carpenters to report on any defects which might be attributable to the seasoning process. We received none, and from a personal inspection of samples surfaced and worked in the above manner, there appeared to be no untoward increase in surface quality and no difficulty in machining.

Anon.: If there is no apparent effect on machinability, what might be the effect of high temperature on strength?

Mr. Calvert: These investigations included an evaluation of possible effects of high-temperature drying upon the strength properties of softwood. Matched strength specimens (air-dried and kiln-dried) were conditioned for a period and were subsequently subjected to static bending and toughness tests. There was no evidence, resulting from these tests, which indicated strength had been adversely affected. Similar tests were conducted on yellow birch specimens (see "High-Temperature Drying of Yellow Birch" by J. L. Ladell, Forest Products Journal, November 1956) with the same result. In fact, in these latter tests an increase in static bending strength was recorded, attributed to the increased specific gravity of the material resulting from higher shrinking and compacting during drying.

Spiral Grain in Second-Growth Douglas-Fir and Western Hemlock[1]

G. K. ELLIOTT[2]

Graduate Student, University of British Columbia, Vancouver, B. C.

Evidence indicates that spiral grain is the normal growth pattern in trees. In both species studied, spiral begins by increasing to the left with age, reaches a maximum, and then decreases through zero and becomes an increasing right spiral. Effect of site was highly significant with both species. On high-quality sites, distance from pith was the chief factor, while on low-quality sites, age from pith had most influence on spiral development.

THE SPIRAL HABIT OF GROWTH is a common manifestation in nature. Spiral development might be considered as an expression of a widespread tendency that is protoplasmic in origin. Certainly the twist found in nature is not restricted to any particular group of organisms. In the animal world there are pronounced twists developed in the group Mollusca, both in the dextral and the sinistral direction. In the plant world, tendrils of the cotton plant and climbing parts of other plants exhibit the phenomenon. Cotton fibers show both left and right spiral development.

The occurrence of spiral development at the subcellular level has become well known in recent years. Spiral trends have been established in muscle fibers, and the spiral arrangement in cellulose fibers is well known (7).[2] The spiral nature of chromosomes as they appear in the dividing nucleus has long been known to the cytologist. With the advent of the electron microscope, the helical nature of the cellulose fibrils in the primary cell walls of cambial tissue in certain plants has been established.

In view of the universal nature of spirality, it is not surprising that the phenomenon is exhibited in trees. Until recently, however, the spiralled tree has been taken as the exception rather than the rule. Recent work in India and in Canada has shown that twist is an expression of the normal growth pattern in trees.

The influence of spiral grain in wood is to cause severe twisting of lumber and plywood. In the primary forest products industries, the presence of spiral grain in the tree results in cross-grained products. The effects of cross-grain on the strength properties of wood has long been established. There is a reduction of 5 per cent in resistance to impact bending when the slope of grain is 1 in 25 (2° 18′); with a slope of 1 in 10 (5° 45′) the reduction is 38 per cent.

Straight-grained wood is essential for such products as barrel staves and all products that require a bent timber, such as furniture. The loss in strength is due to the fact that basic stresses are established on the basis that the forces act parallel to the grain or at right angles to it; therefore it is evident that any departure in grain alignment is registered as a reduction in the strength of the wood piece.

Literature Survey

The literature concerning observations and theories pertaining to spiral grain in plants goes back to C. B. Clarke, who wrote a paper on "Right-hand and Left-hand Contortion" in the Journal of the Linnaean Society in 1881. Many papers have been written since, most of them reporting the phenomenon, but few are concerned with the mechanism. Real experimentation began with the classic contributions of H. G. Champion (1, 2, 3), who followed up the observations of E. A. Smythies in *Pinus longifolia* (Roxb.). Sir Harry Champion's work between 1925 and 1930 remains the basis for contemporary study in the field.

The earliest of Champion's experiments (2) dealt with the possibilities of inheritance governing twist. As a result of progeny tests on seeds from selected localities ranging from areas where spiral was prominent to areas where spiral was rare, involving some 6,000 seedlings, the following conclusions were drawn:

1) Most trees that exhibit spiral begin to show it as a left twist, which changes to a right with the passage of time.
2) There is a certain amount of fluctuation in fiber direction, which accounts for exceptions to this rule.
3) Where twist is frequent, the tendency to produce it is capable of being transmitted from one generation to the next.
4) Conditions found in existing forests make the inheritance of twist as an acquired character difficult to accept.

Following up the results of this investigation, Champion combined seed of five parentage types, on four areas in every combination, and showed that (3):

1) From a 100 per cent twisted-parent crop, some two-thirds of the second rotation crop will be twisted.
2) Seed from straight-grained areas gives a crop virtually free of twist.
3) In all cases, the seedlings reflect to some degree the twist of their parents.

These experiments show a clear-cut indication of the role of heredity in the development of spirality.

Recent work at the Vancouver Laboratory of the Forest Products Laboratories of Canada, by P. L. Northcott (5), has shown that the spiral habit is the normal growth pattern in trees. The pattern of spirality established by Champion was found in other coniferous species. Kennedy and Elliott (4) showed a relationship between rate of growth and spiral development in red alder (*Alnus rubra* Bong).

In a recent paper on the development of spiral grain in *Pinus longifolia* in South Africa, Rault and Marsh (6) have shown that the quality of the site and the age of the tree are important factors that affect spirality.

The universal nature of spiral development is therefore manifest in the normal growth pattern of trees. Spirality is considerably influenced by the genetic make-up of the individual and the environment of the individual, with particular regard to those factors governing growth rate.

Materials and Methods

The material for this study was collected from sample plots on the University Research Forest at Haney, B. C., in the Lower Fraser Valley. The forest is considered to be typical of the British Columbia coastal forest, and is predominantly a mixture of Douglas-fir, western hemlock, and western red cedar. The area from which the sam-

[1] Submitted April, 1957, as a 1957 Wood Award Entry.

[2] Mr. Elliott is now a graduate student at the University College of North Wales, Bangor, North Wales, Great Britain.

ples were taken is even-aged, the result of a fire in the old-growth timber in 1867. Certain discrepancies in the ages do appear as shown in the data sheets, (Tables 1–3), but for the purposes of practical forestry the area is considered even-aged.

Three plots were chosen, with site indices 90, 110, and 140, a common range of site quality on the area, representing a rather poor forest growth (Site V) through to a rather good forest growth (Site III).[3] Two species, Douglas-fir *(Pseudotsuga menziesii* (Mirb) Franco), and western hemlock *(Tsuga heterophylla* (Raf) Sarg), were sampled from each plot. The individual trees were selected from two crown classes, the Dominant-Codominant class and the Intermediate class. Three individuals from each crown class for each species were collected. This gave a total of 36 trees, which included 18 from each species, 6 from each site per species, and averaged 3 from each crown class per site.

The trees were felled and cross-sectional discs were taken at the 4½-foot (breast height) level. The method of measuring the spiral was that adopted by Kennedy and Elliott (4), and developed at the Vancouver Laboratory of the Forest Products Laboratories of Canada. The discs were split with a straight-edged wedge along a convenient diameter free of knots or other defects that might cause abnormal grain deviation. The split followed the grain and exposed the spiral pattern; the operation was done while the cross-section was in the green condition to prevent spiral changes due to differential shrinkage.

Actual spiral measurements were made at 10-year increments from the pith. The increments were measured on either side of the pith, and an average value for each decade was calculated. The pith of each section was chosen as the reference line from which the spiral determinations were made. The measuring instrument was a modified bevel protractor accurate to within ½°. The knife edge was placed firmly on the pith, and at each decade the angle of the grain was measured by means of the adjustable protractor, either as a right or a left deviation from the pith axis. The radius from the pith to each spiral measurement was also noted.

The experimental design therefore incorporates the effect on spiral of age from the pith, radius from the pith, crown class, and site. The primary influences were tested in an analysis of variance, the effect of age and diameter on spiral were graphically represented, and regression analyses were made on these curves Figs. 3 to 14. Graphical representations of the data are not easily analysed when the actual spiral angles, which vary from left to right within a given cross-section, are used. Hence the concept of the *absolute* spiral angle was used, by which the direction of spirality is ignored. This is a valid concept from the practical point of view since only the absolute degree of spirality affects timber properties. Furthermore, the absolute spiral angle at any point was plotted as the *cumulative* figure, which represents the total number of degrees through which the spiral had progressed from the pith. The concept is

[3] Site quality as defined from U. S. Dept. of Agriculture Technical Bulletin No. 201, "The yield of Douglas fir in the Pacific Northwest", McArdle and Meyer.

Table 1.—ACTUAL AVERAGE AND CUMULATIVE ABSOLUTE SPIRAL ANGLE, IN TERMS OF RADIUS AND AGE FROM PITH, PLOT 1 (CROSS-SECTIONAL DISC TAKEN AT HEIGHT OF 4½ FEET)

Tree C Inter. Fir

Act[1]	C.A.S.[2]	Rad[3]	Age[4]
1L	1	1.4	10
¼L	1½	2.6	20
½R	2½	3.5	30
2R	4	3.9	40
2¾R	4¾	4.3	50
3¾R	5¾	4.7	60
5½R	7½	5.0	70
5½R	7½	5.2	80

Tree D Dom. Fir

Act	C.A.S.	Rad	Age
¾L	¾	0.9	10
½L	1	1.7	20
1½L	2	3.0	30
¾L	2¾	3.7	40
1¼L	3¼	4.2	50
½R	4	4.5	60
1¼R	5¾	4.9	70
2¾R	7¼	5.2	78

Tree E Dom. Fir

Act	C.A.S.	Rad	Age
0	0	1.0	10
¼L	¼	2.1	30
1R	1½	2.9	30
½R	2	3.6	40
2R	3½	4.3	50
4R	5½	5.0	58

Tree H Codom Fir

Act	C.A.S.	Rad	Age
1½L	1½	1.5	10
¾L	2¼	2.8	20
½L	2½	3.8	30
0	3	4.3	40
½R	3½	4.5	50
¾R	3¾	4.6	60
1½R	4¼	4.8	65

Tree F Inter. Fir

Act	C.A.S.	Rad	Age
½R	½	1.5	10
¾L	1¾	3.1	20
0	2½	4.0	30
0	2½	4.5	40
2½R	5	5.1	50
4½R	7	5.4	60
5½R	8	5.7	70

Tree B Inter. Fir

Act	C.A.S.	Rad	Age
¼R	¼	1.2	10
2L	2¼	2.3	30
1¼L	3	3.5	30
1¾L	3½	4.2	40
0	5¼	4.7	60
½L	5¾	5.1	70

Tree K Dom. Hemlock

Act	C.A.S.	Rad	Age
1¾L	1¾	1.6	10
1¾L	1¾	3.7	20
2½L	2½	5.4	30
3L	3	7.0	40
2¾L	3¼	8.3	50
3L	3½	9.1	60
3¾L	4¼	10.0	70
3½L	4½	10.6	75

Tree A Codom Hemlock

Act	C.A.S.	Rad	Age
2L	2	0.6	10
1½L	2½	1.6	20
½R	3½	2.5	30
1¾R	4¾	3.3	40
¾R	5¾	4.0	50
¼R	6¼	4.5	60
1¾R	7¾	5.0	70

Tree I Codom Hemlock

Act	C.A.S.	Rad	Age
2½L	2½	1.4	10
2¾L	2¾	2.0	20
1¼L	4¼	2.6	30
¼R	5¾	3.0	40
1½R	7	3.6	50
2¾R	8¼	4.3	60
3¼R	8¾	4.9	70

Tree L Inter Hemlock

Act	C.A.S.	Rad	Age
0	0	1.0	10
1R	1	1.4	20
3R	3	2.6	30
2R	4	3.2	40
1½R	4½	3.7	50
3½R	6½	3.9	60
3¾R	6¾	4.2	70

Tree G Inter Hemlock

Act	C.A.S.	Rad	Age
½L	½	1.1	10
1½L	1½	1.8	20
½L	2½	2.5	30
1¾L	3¾	3.1	40
2L	4	3.6	50
2½L	4½	4.0	60
2L	5	4.3	70

Tree J Inter Hemlock

Act	C.A.S.	Rad	Age
0	0	0.9	10
1¾R	1¾	1.8	20
½R	3	3.0	30
¾R	3¼	4.2	40
2R	4½	5.0	50
3¼R	5¾	5.6	60
5R	7½	5.8	70

[1] Actual average spiral angle, in degrees.
[2] Cumulative absolute spiral angle, in degrees.
[3] Radius from pith, in inches.
[4] Age from pith, in years.

Table 2.—ACTUAL AVERAGE AND CUMULATIVE ABSOLUTE SPIRAL ANGLE, IN TERMS OF RADIUS AND AGE FROM PITH, PLOT II (CROSS-SECTIONAL DISC TAKEN AT HEIGHT OF 4½ FEET)

Tree D Dom. Fir

Act[1]	C.A.S.[2]	Rad[3]	Age[4]
3L	3	2.3	10
¾L	5¼	3.0	20
0	6	3.9	30
½L	6½	4.3	40
1R	8	4.7	50
0	9	5.0	60
½R	9½	5.1	63

Tree E Dom. Fir

Act	C.A.S.	Rad	Age
¾L	¾	2.0	10
1L	1	3.3	20
½L	1½	4.3	30
½R	2½	5.2	40
½R	2½	5.8	60
½R	2½	6.5	60

Tree I Dom. Fir

Act	C.A.S.	Rad	Age
0	0	1.3	10
1¾R	1¾	2.6	30
2½R	2½	2.5	30
2½R	2½	3.1	50
2½R	2½	3.5	50
1¾R	3¼	4.0	58

Tree F Dom. Fir

Act	C.A.S.	Rad	Age
1L	1	1.7	10
1R	3	2.9	20
¼L	4¼	3.4	30
1L	5	4.2	40
¾L	5¼	4.6	50
¾R	6¾	5.2	58

Tree J Inter Fir

Act	C.A.S.	Rad	Age
1¼L	1¼	1.3	10
½L	2	2.0	20
½L	2	2.5	30
½L	2	2.7	40
¾L	2¼	2.9	50
¾L	2¼	3.1	60

Tree C Inter Fir

Act	C.A.S.	Rad	Age
1¼L	1¼	1.5	10
½L	2	2.1	20
1¼R	3¾	2.3	30
2R	4½	3.2	40
2½R	5	3.7	50
3R	5½	3.9	50

Tree K Codom Hemlock

Act	C.A.S.	Rad	Age
1¾L	1¾	1.0	10
¼L	3¼	1.5	20
½R	4	2.0	30
2¾R	6¼	2.4	40
4R	7½	2.8	50
3R	8½	3.1	60

Tree G Codom Hemlock

Act	C.A.S.	Rad	Age
1¾L	1¾	1.4	10
0	2½	2.2	20
1R	3½	3.2	30
1¾R	4¼	3.8	40
4¼R	6¾	4.5	50
6R	8½	5.0	58

Tree B Codom Hemlock

Act	C.A.S.	Rad	Age
2L	2	1.2	10
¾L	3¼	2.6	30
1¾L	4¼	3.7	40
1½L	4½	4.3	50
¾L	5¼	4.8	50
0	6	5.3	58

Tree L Inter Hemlock

Act	C.A.S.	Rad	Age
1½L	1½	1.3	10
1¼L	1¾	1.8	20
¼L	2¾	2.2	30
1R	4	2.7	40
2½R	5½	3.3	50
3½R	6½	4.1	60

Tree A Inter Hemlock

Act	C.A.S.	Rad	Age
1½L	1½	1.0	10
1½R	4½	1.9	20
1L	7	2.5	30
¼L	7¾	3.3	40
1¼R	9¼	3.6	50
1¼R	9¼	3.9	55

Tree H Inter Hemlock

Act	C.A.S.	Rad	Age
2¾L	2¾	1.1	10
1½L	4¼	2.2	30
1¼L	4½	2.9	40
1L	4¾	3.5	50
½L	5¼	4.1	60

[1] Actual average spiral angle, in degrees.
[2] Cumulative absolute spiral angle, in degrees.
[3] Radius from pith, in inches.
[4] Age from pith, in years.

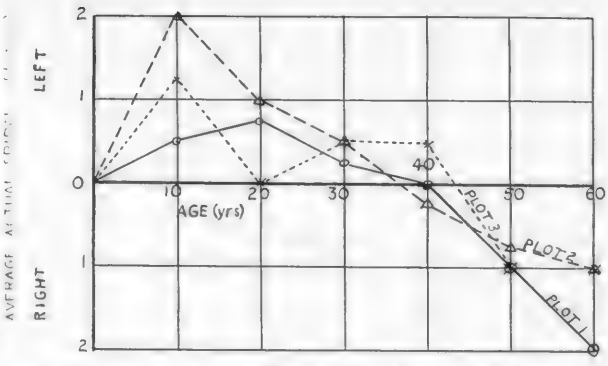


Fig. 1.—Actual spiral vs age at breast height for Douglas-fir.

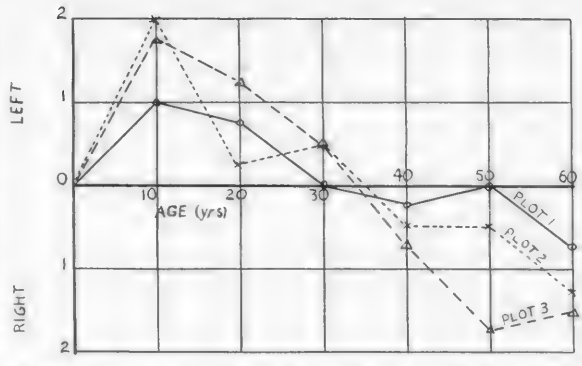


Fig. 2.—Actual spiral vs age at breast height for western hemlock.

Table 3.—ACTUAL AVERAGE AND CUMULATIVE ABSOLUTE SPIRAL ANGLE, IN TERMS OF RADIUS AND AGE FROM PITH, PLOT III (CROSS-SECTIONAL DISC TAKEN AT HEIGHT OF 4½ FEET)

Tree H Dom Fir

Act[1]	C.A.S.[2]	Rad[3]	Age[4]
1½ R	1¼	0.9	10
1R	1½	1.6	20
0	2½	2.1	30
1¼ L	3¾	2.5	40
1¾ L	3¾	3.0	50
1¼ L	3¾	3.3	60

Tree I Dom Fir

Act	C.A.S.	Rad	Age
3¼ L	3½	0.7	10
2¾ L	4	1.5	20
1½ L	4¾	2.2	30
1¼ L	5	2.7	40
¾ L	5½	3.2	50
¾ L	5½	3.7	60

Tree J Codom Fir

Act	C.A.S.	Rad	Age
3L	3	1.0	10
1¾ L	4¾	1.7	20
1R	7	2.6	30
1¾ R	7¾	3.0	40
4¼ R	10¼	3.8	50
5¾ R	11¾	4.3	58

Tree F Inter DF

Act	C.A.S.	Rad	Age
3L	3	1.0	10
1L	5	1.7	20
¼ L	5¾	2.3	30
¾ R	6¾	2.9	40
½ R	7	3.5	50
1R	7½	4.6	61

Tree C Inter Fir

Act	C.A.S.	Rad	Age
2½ L	2½	1.3	10
2½ L	2½	1.9	20
¾ L	4¼	2.4	30
¼ R	5¼	2.9	40
¼ R	5¼	3.3	50
1R	6	3.7	60

Tree E Inter Fir

Act	C.A.S.	Rad	Age
2½ L	2¼	0.9	10
1¼ R	5¾	1.5	20
2¼ L	9¼	1.7	30
1R	12½	1.9	40
1¼ R	12¾	2.2	50
¾ R	13¼	2.3	60

Tree G Dom Hemlock

Act	C.A.S.	Rad	Age
3½ L	3½	0.4	6
3¼ L	3¾	0.6	10
3½ L	4	1.0	14
3½ L	4	1.3	20
1½ L	6	1.9	30
½ R	8	2.5	40
1½ R	9	2.8	50
2R	9½	3.2	60
2R	9½	3.3	62

Tree A Dom Hemlock

Act	C.A.S.	Rad	Age
1¼ L	1¼	1.0	10
1¼ L	1¼	1.7	20
1¼ L	1¼	2.5	30
1R	3½	3.2	40
3½ R	6	3.9	50
3¼ R	6¼	4.7	60
2¼ R	7¼	5.0	62

Tree L Dom Hemlock

Act	C.A.S.	Rad	Age
2½ L	2½	1.1	10
2½	2½	1.8	20
1¼ L	3¾	2.2	30
¼ L	4¾	2.6	40
0	5	3.2	50
¼ R	5¼	3.8	60
¼ R	5¼	3.9	62

Tree K Dom Hemlock

Act	C.A.S.	Rad	Age
½ L	½	1.0	10
0	1	1.8	20
1½ R	2½	2.7	30
1¾ R	2¾	3.7	40
3R	4	4.4	50
3¼ R	4¼	4.8	58

Tree D Inter Hemlock

Act	C.A.S.	Rad	Age
4L	4	0.4	6
2½ L	5½	0.7	10
2L	6	1.2	20
1¾ L	6¼	1.7	30
1¾ L	6¼	2.3	40
1¼ L	6¾	3.0	50
0	8	3.8	61

Tree B Inter Hemlock

Act	C.A.S.	Rad	Age
1L	1	1.1	10
¾ L	1¼	1.9	20
½ R	2½	2.5	30
2¾ R	4¾	2.9	40
2R	5½	3.4	50
1R	6½	3.9	60

[1]Actual average spiral angle, in degrees.
[2]Cumulative absolute spiral angle, in degrees.
[3]Radius from pith, in inches.
[4]Age from pith, in years.

best explained by an example: consider a tree that attains a spiral of 2°L at 10 years and goes on to develop a spiral of 2°R at 30 years. If it is assumed that between 10 and 30 years the spiral changes are consistent, then the *actual spiral* recorded by decades will be:

10 years 2°L 20 years 0 30 years 2°R

The *absolute spiral*, a measure of angular deflection irrespective of direction, does not exceed 2° because lumber from the tree at this age will not show a deflection greater than 2° from the straight-grained condition. The *cumulative absolute spiral* is a measure of the sum total deflection from the straight-grained condition, and is a measure of the potential spiral attainable by the tree. From the example quoted, the tree at 30 years has a spiral of 2°R; to reach this condition it has passed through zero to 2°L. The sum total deflection from zero spiral angle, that is, the cumulative absolute spiral, is the sum of the two measured deflections, or 4°.

Where there is no change of direction in spiral development, the *actual spiral* is equal to the *cumulative absolute spiral*.

It is possible that there are inadequacies in the sampling technique, since all the samples were taken from snow-broken trees. This, although enabling the data to be collected from actual sample plots, may have led to an inaccurate sampling technique since it has been stated by Champion (1) that trees that exhibit spiral are able to withstand the effect of snow pressure better than are straight-grained trees. No figures are available, and should the conjecture be correct, the sample can only err on the conservative side.

Certain real differences in the classification by sites may not have been clearly defined, since no really domi-

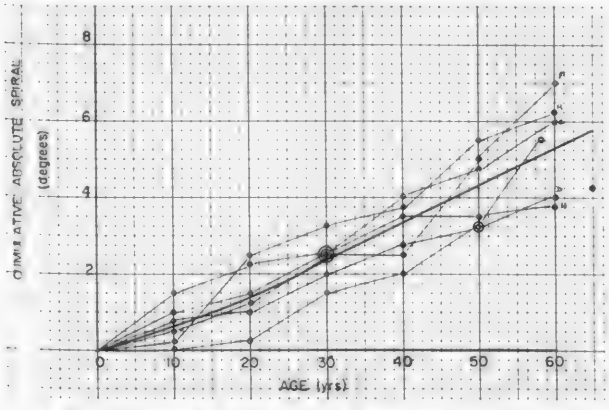


Fig. 3.—Cumulative absolute spiral vs age. Plot I, Douglas-fir.

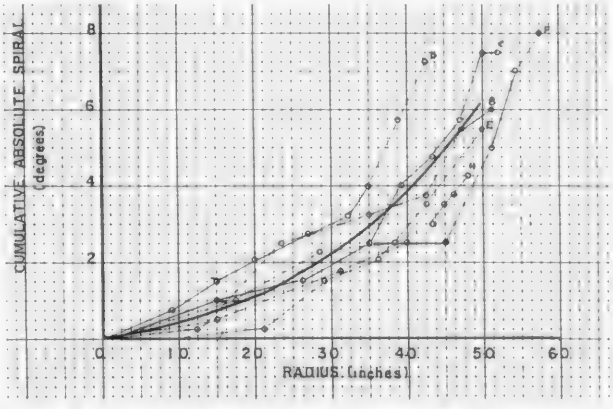


Fig. 4.—Cumulative absolute spiral vs radius. Plot I, Douglas-fir.

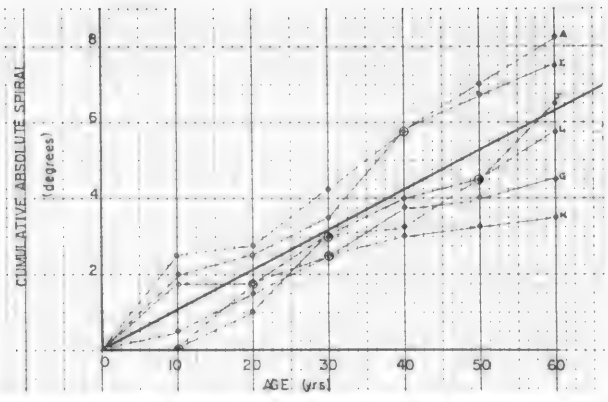


Fig. 5.—Cumulative absolute spiral vs age. Plot I, western hemlock.

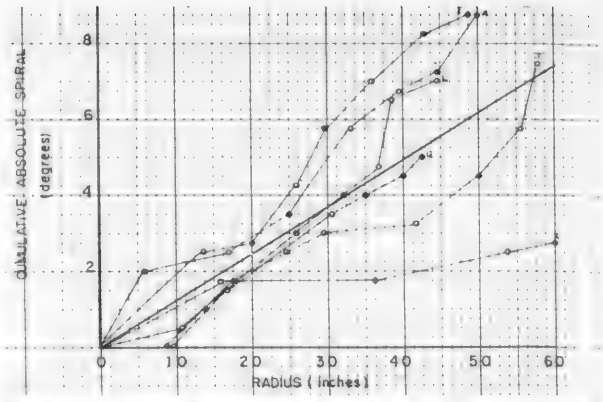


Fig. 6.—Cumulative absolute spiral vs radius. Plot I, western hemlock.

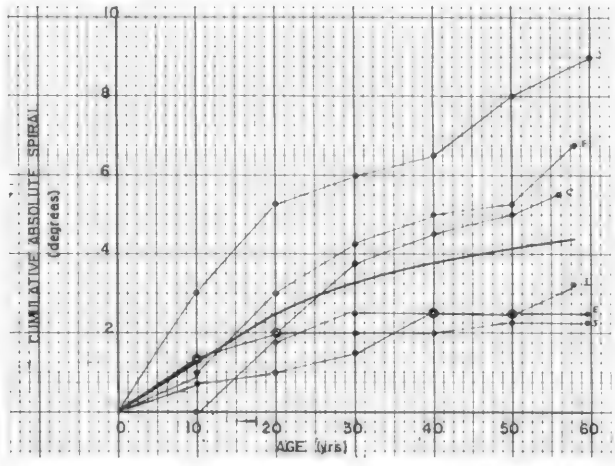


Fig. 7.—Cumulative absolute spiral vs age. Plot 2, Douglas-fir.

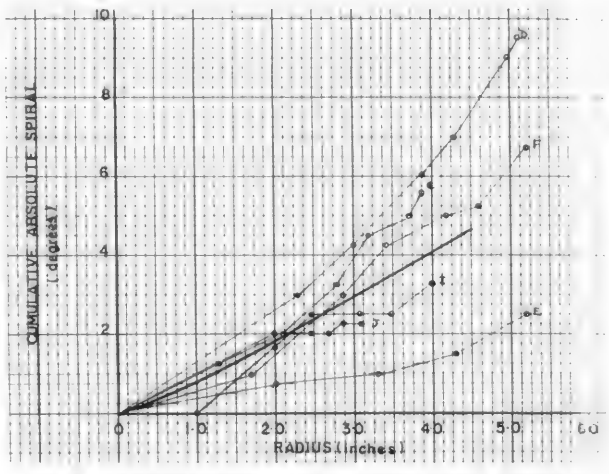


Fig. 8.—Cumulative absolute spiral vs radius. Plot 2, Douglas-fir

nant trees were available from the plots. The sample taken from the Dominant-Codominant crown class does not represent the best trees on each plot, but rather the 'next-best' trees. Since site classification is determined from the Dominant crown class, maximum differences may not have been available. Sufficient evidence has been gleaned, however, to show that there are definite differences in spirality between different site classes.

Results

I. General Pattern: The general pattern of spirality observed in Douglas-fir and western hemlock is shown graphically in Figs. 1 and 2. It is emphasized that these data represent only average values calculated to the nearest ¼°. A great deal of variation exists between individual trees, as Tables 1 through 3 show.

Certain conclusions can be drawn from these average data. Considering the 4½-foot (Breast Height) level, and the average figures for both species on all plots, the general trend is an increase, with age, from zero to a maximum left spiral, which decreases in intensity and ultimately returns to zero. The decrease is continued as an increasing right spiral. Some trees, however, never exhibit a left spiral, (Plot I, tree L, Table 1), while others show a fluctuating spiral from left to right and back again to left (Plot II, tree F, Table 2). Others showed a high initial left spiral that although decreasing with increasing age, never actually attains a right spiral (Plot II, tree J, Table 2). Furthermore, some trees developed an immediate right spiral that continues throughout the life of the tree (Plot I, tree J, Table 1). All these combinations of spirality show the variation that can be expected around the general trend.

II. The Influence of Age and Radius Between Sites: In Figs. 3, 7, and 11 are shown the effect of age on spiral development in Douglas-fir expressed as the *cumulative absolute spiral* at the B.H. level. The average lines drawn in these figures are curvilinear and show that the spiral angle changes most rapidly in the first years and to a lesser degree thereafter. At comparable ages, the cumulative absolute spirals on the three plots are somewhat variable. Plots I and II, the better sites, showed a very close relationship; Plot III, the poorest, always showed a higher spiral angle. Thus at 50 years, Plot I shows a cumulative absolute spiral of 4¼°, Plot II of 4¼°, Plot III of 7¼°.

Because spiral angle changes with age from the pith, it must also change with distance from the pith. Figs. 4, 8, and 12 indicate this change when cumulative absolute spiral is plotted against radius. Again there is a close similarity between Plots I and II, and a marked difference between Plot III and the other plots. Thus at a 4-inch radius, Plot III shows a cumulative absolute spiral of 7¼° whereas the corresponding spirals for Plots I and II are 3¾° and 4° respectively. Some explanation of this dissimilarity is indicated in Fig. 15, which shows the relationship between radius and age for the Douglas-fir of all three plots. At 50 years of age, the average radius of Plot III is 3.1 inches, whereas the average Plot II tree has a radius of 4.2 inches and an average Plot I tree 4.5 inches. Therefore, because of the coincidence of the relative growth rates of the fir on Plots I and II, the same relative spiral, expressed as cumulative absolute spiral, is developed. The greatest change in spiral occurs on Plot III; it follows then that the slower growth rate produces the greatest change in spiral angle.

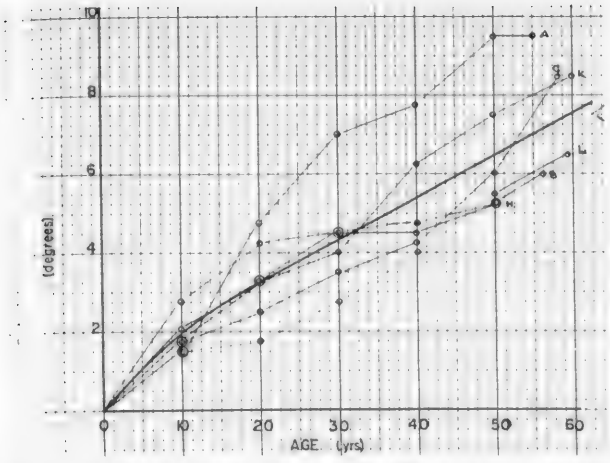


Fig. 9.—Cumulative absolute spiral vs age. Plot 2, western hemlock.

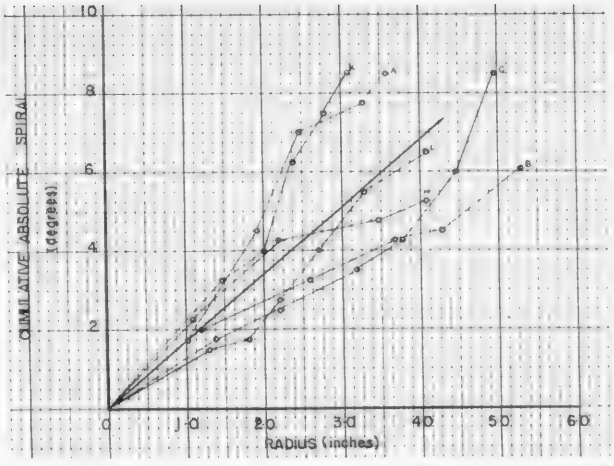


Fig. 10.—Cumulative absolute spiral vs radius. Plot 2, western hemlock.

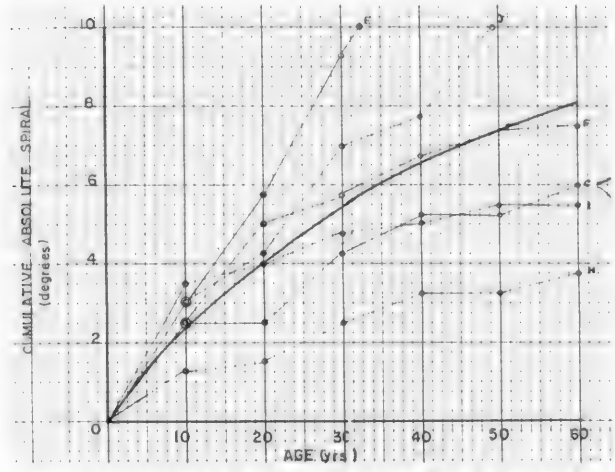


Fig. 11.—Cumulative absolute spiral vs age. Plot 3, Douglas-fir.

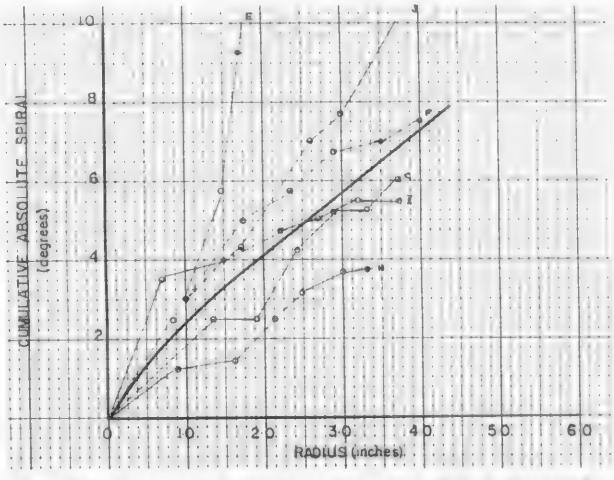


Fig. 12.—Cumulative absolute spiral vs radius. Plot 3, Douglas-fir.

A similar condition exists with hemlock, where again the greatest change in spiral occurs on the poorer site. The effect is not so well marked as in the fir because the difference between the three plots is not so well defined. Thus Figs. 5, 13, and 9 indicate that at 50 years the cumulative absolute spiral developed for Plots I, II and III are 5¼°, 5¾° and 6½° respectively. The corresponding radii at 50 years (Fig. 16) are 4.7 inches, 3.8 inches and 3.4 inches. In this case, Plots II and III show the closest resemblance to each other on the Age-radius graph (Fig. 16). From the information cited for the Douglas-fir it is to be expected that at a given radius Plots II and III will differ from Plot I. At a 4.0-inch radius, Plot II shows a cumulative absolute spiral of 6¾°, Plot III of 6½°, and Plot I of 5°.

It is evident that both age and radius have considerable influence upon spiral development in both Douglas-fir and western hemlock. In the general analysis of variance, Tables 6 and 7, age has a highly significant effect upon spiral for both species. With a more complete statistical analysis, shown in Tables 4 and 5, the simple correlation coefficients for age and for radius are significant in all cases.

III. Influence of Age and Radius Within Sites: The foregoing results indicate that, where a considerable difference in growth rate occurs between sites, then the difference in spiral development may be attributed to site factors that control growth rate. The problem remains as to which is the more important factor governing the spiral, age or radius? The data at the BH level were subjected to a statistical analysis to determine the relative importance of age and radius on cumulative absolute spiral. The correlation coefficients are shown in Tables 4 and 5. The results may be summarized as follows:

1) All zero-order or simple correlation coefficients were highly significant. Age and all other factors linearly associated with it were highly correlated with spirality for both species and on all sites. Radius was strongly correlated with spirality for both species and on all sites. The weakest correlation, which was with spiral and radius for Douglas-fir on Plot III, had an "r" of 0.394, which was well within the limits of acceptability at the 5 per cent level of significance.

2) The relative importance of radius and age on cumulative absolute spiral angle can be seen by comparing partial correlation coefficients. For fir, the effect of radius on spiral, with age held constant, is small for Plots III and II. However for Plot I the effect of radius is highly significant, but when radius is held constant the effect of age is small. In this case, radius seems to have the strongest effect on spirality. In Plot II, the effect of radius is stronger than the effect of age. In Plot III, where the simple correlation of spiral against radius is lower than that of spiral against age, the effect of age shows a stronger influence on spirality. This is also evident in the high partial correlation coefficient of spiral and age against radius.

As far as hemlock is concerned, the partial correlation coefficients indicate the stronger influence of radius on cumulative absolute spiral on all plots. On Plot III, the influence of age

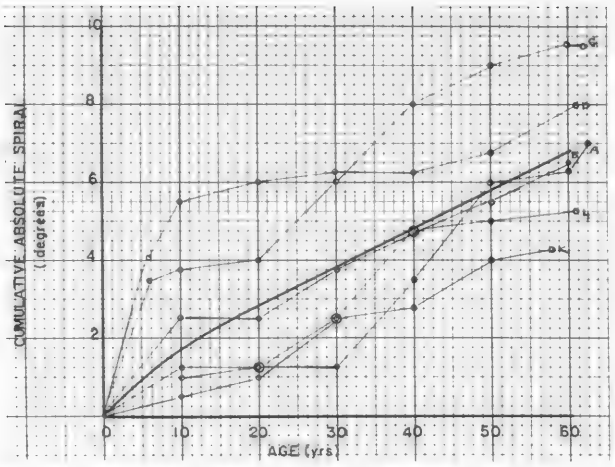


Fig. 13.—Cumulative absolute spiral vs age. Plot 3, western hemlock.

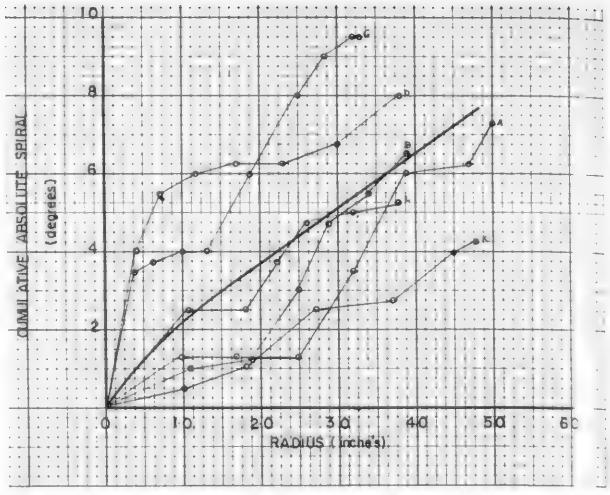


Fig. 14.—Cumulative absolute spiral vs radius. Plot 3, western hemlock.

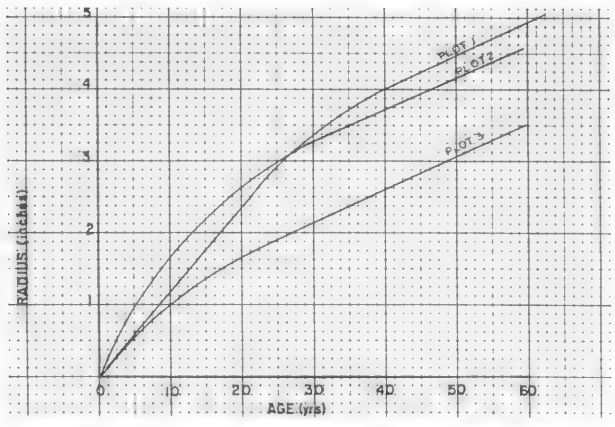


Fig. 15.—Radius vs age at breast height, Douglas-fir.

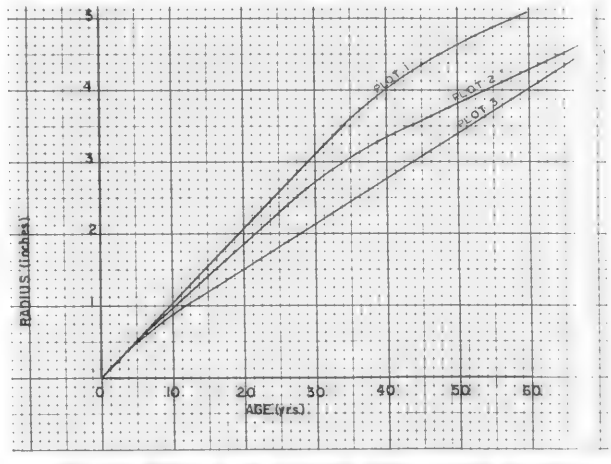


Fig. 16.—Radius vs age at breast height, western hemlock.

equals that of radius, as shown by the partial correlation coefficients. The simple coefficients indicate the stronger influence of age, particularly on Plot III. The indication is that, on the slower growing sites, age has the predominant influence on the change in spiral angle. On the faster growing sites, the influence of radius is increased to predominate the influence of age. Both factors have a highly significant effect on the cumulative absolute spiral.

IV. Influence of Crown Class: In Tables 6 and 7 are shown analyses of variance for the whole experiment. From these tables it is evident that crown class has the least effect on the development of spiral characters. The effect has no significance with hemlock, and just achieves an acceptable significance with fir. Visual examination of the basic data sheets (Tables 1–3) will confirm that, within a given site and within one species, a division into crown classes is not an important factor.

V. Influence of Site: Differences in the spiral characteristics of the two species on the three plots have already been discussed. The site differences are most marked with Douglas-fir, and from the analysis of variance (Table 6) the effect of site is shown to be highly significant. On the same three plots where differences in the growth rate of western hemlock are not well defined, the differences that exist do not show so high a significance as fir (Table 7). In both cases, the effect under test is the cumulative absolute spiral, which is a measure of the change in spiral angle. Figs. 1 and 2 show the average actual spirals developed by each species on each plot. The site of slowest growth in each case shows the strongest initial spiral development, and the greatest subsequent

Table 4.—CORRELATION COEFFICIENTS BETWEEN RADIUS, AGE, AND CUMULATIVE ABSOLUTE SPIRAL: DOUGLAS-FIR

Classification	Statistic	Plot 1	Plot 2	Plot 3
Zero	rspiral.age	0.892[5]	0.558[5]	0.562[5]
Order	rspiral.radius	0.957[5]	0.619[5]	0.394[2]
Correlations	rage.radius	0.969[5]	0.845[5]	0.908[5]
Partial	rspiral age.radius	0.0488	0.264	0.533[4]
Correlations	rspiral radius.age	0.883[5]	0.333[1]	0.338[1]

[1]Significant at 0.1%.
[2]Significant at 0.05%.
[4]Significant at 0.01%.
[5]Significant at 0.001%.

Table 5.—CORRELATION COEFFICIENTS BETWEEN RADIUS, AGE, AND CUMULATIVE ABSOLUTE SPIRAL: WESTERN HEMLOCK

Classification	Statistic	Plot 1	Plot 2	Plot
Zero	rspiral.age	0.656[5]	0.842[5]	0. [illegible]
Order	rspiral.radius	0.526[4]	0.816[5]	0. [illegible]
Correlations	rage.radius	0.767[5]	0.882[5]	0. [illegible]
Partial	rspiral age.radius	0.463	0.463[3]	0. [illegible]
Correlations	rspiral radius.age	0.454	0.630[5]	0. [illegible]

[3]Significant at 0.02%.
[4]Significant at 0.01%.
[5]Significant at 0.001%.

Table 6.—DOUGLAS-FIR—ANALYSIS OF VARIANCE TO SHOW COMPARATIVE EFFECT OF SITE, CROWN CLASS, AND AGE ON CUMULATIVE ABSOLUTE SPIRAL

Effect	DF.	SS	MS	Vr.
Site	2	153.5602	76.7801	21.1527[3]
Crown Class	1	16.6245	16.6245	4.5800[1]
Age	5	267.2407	53.4481	14.7248[3]
Residual	99	350.9355	3.6298	
Total	107	788.3519		

[3]ignificant at 0.1% level.
[1]ignificant at 5.0% level.

Table 7.—WESTERN HEMLOCK—ANALYSIS OF VARIANCE TO SHOW COMPARATIVE EFFECT OF SITE, CROWN CLASS, AND AGE ON CUMULATIVE ABSOLUTE SPIRAL

Effect	DF.	SS	MS	Vr.
Site	2	22.9306	11.4653	4.4509[1]
Crown Class	1	3.7939	3.7939	1.4728
Age	5	294.1441	58.8288	22.8381[3]
Residual	99	255.0221	2.5759	
Total	107	579.8907		

[3]Significant at 0.1% level.
[1]Significant at 5.0% level.

spiral change. The weakest initial development and the least change in spiral angle is a characteristic of the site where growth is fastest. Spiral change on the better of the three sites sampled is governed to a large extent by radius, so that rapid increase in radius may tend to result in an increase in spirality.

Conclusions

1) There is a general pattern of spiral development in both Douglas-fir and western hemlock on the three sites studied. This pattern takes the form of an initial left spiral which decreases to the left, passes through zero, and becomes a right spiral with increasing age and radius.

2) Individual trees of the same species and on the same site, although contributing to the general pattern, vary considerably in their individual spiral development.

3) The highest average actual spirals are measured on the poorest sites. The greatest change in spiral angles occurs under these conditions, so that in a general way the slowest growing trees exhibit the greatest amount of spiral development.

4) On the slower growing sites, the change in spiral is highly correlated with the age of the tree. On sites of higher quality, although age is correlated highly, radius exerts the strongest influence on spirality.

Literature Cited

1. Champion, H. G. 1925. Contributions toward a knowledge of twisted fibre in trees. Indian For. Rec. 11, Pt. II, pp. 11–80.
2. Champion, H. G. 1927. An interim report on the progress of investigations into the origin of twisted fibre in *Pinus longifolia* Roxb. Indian For., 53 (1), pp. 18–22.
3. Champion, H. G. 1930. Second interim report on the progress of investigations into the origin of twisted fibre in *Pinus longifolia* Roxb. Indian For., 56 (12), pp. 511–20.
4. Kennedy, R. W., and G. K. Elliott. Spiral grain in red alder (*Alnus rubra* Bong)—(In press).
5. Northcott, P. L. The mechanism of spiral grain (In press).
6. Rault, J. P. and E. K. Marsh. 1952. The incidence and implications of spiral grain in *Pinus longifolia* Roxb. in South Africa and its effect on converted timber. S. Afr. For. Prod. Inst. Pretoria West, Paper presented at Comm. For. Conf. Canada.
7. Roa, H. S. 1954. The phenomenon of twisted trees. Indian For. 80 (3), pp. 165–70.

Factors Affecting the Amount of Naphthalene in Condensate During Boiling Under Vacuum in Creosote[1]

G. BRAMHALL and W. M. CONNERS

Vancouver Laboratory, Forest Products Laboratories of Canada, Vancouver, B. C.

An empirical formula was developed to relate the proportions of naphthalene and water in the condensate formed when wood is creosoted by the Boulton process. The proportion of naphthalene increases with increasing temperature and with decreasing pressure.

WHEN A CHARGE OF GREEN WOOD is boiled under vacuum in creosote by the Boulton process, a condensate is formed that contains both water and crystalline solids. The solids consist of the more volatile constituents of creosote and are rich in naphthalene. These crystals tend to plug the lines leading from the retort through the condenser to the drip tanks, and in this way can be very troublesome.

As a result of an investigation of wood treatments involving 11 charges of poles at the Vancouver Laboratory of the Forest Products Laboratories of Canada, it was observed that the proportion of naphthalene in the condensate increased as higher creosote temperatures were used. It was reasoned that a definite mathematical relationship should exist between this proportion of naphthalene and the temperature of the creosote. Accordingly, the results of the 11 charges were analyzed to establish this relationship.

The creosote used in these charges conformed, when purchased, to the American Wood Preservers' Association standard P1 for coal tar creosote. It was not analyzed at the start of the 11 charges reported here; rather, it had been used repeatedly in other experiments before this particular series. It

[1] A contributed paper (September, 1957) from the Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

The Authors: George Bramhall received B. A. Sc. from U. of British Columbia. He was research and control engineer at Vancouver Plywoods from 1946-49, has been forest products engineer at the Vancouver Laboratory since 1949.

W. M. Conners received B. A. Sc. from U. of Toronto, formerly was treating operator and manager of treating plant for Canada Creosoting Co. Ltd. He joined the Vancouver Laboratory in 1948 as head of the Wood Preservation Unit.

Table 1.—DISTILLING CHARACTERISTICS OF CREOSOTE AFTER SERIES OF EXPERIMENTS

up to 210°C	(up to 410°F)	Nil
210°–235°C	(410°–455°F)	2.22
235°–270°C	(455°–518°F)	23.81
270°–315°C	(518°–599°F)	24.90
315°–355°C	(599°–671°F)	20.64
over 355°C	(over 671°F)	28.43
		100.00

Table 2.—CHARACTERISTICS OF POLES BOILING UNDER VACUUM IN CREOSOTE

Charge	Species	Length	Av. dia. (in.)	M.C. (%)	Weight (lb.
43	Douglas-fir	16′, 4½″	13.6	56	69
46	Western hemlock	16′	9.4	56	30
44	Douglas-fir	16′, 4½″	12.4	56	560
48	Western hemlock	15′, 11″	12.8	47	519
49	Western hemlock	16′	13.4	43	52
52	Western hemlock	16′	13.2	36	491
45	Western hemlock	16′	11.8	56	43
47	Western hemlock	16′	14.1	47	6
50	Western hemlock	16′, 1¼′	12.1	43	4
51	Western hemlock	16′	14.2	36	5
53	Western hemlock	16′	13.8	35	5

was analyzed immediately after these charges, however, and its characteristics are listed in Table 1. No significant change in the distilling characteristics of the creosote was thought to have occurred during the course of these experiments, particularly since the working tank contained 3400 pounds of creosote, and only 100 pounds were used per charge.

Experimental

The series of experiments included 11 charges, each containing one pole 16 feet long. Charges 43 and 44 were Douglas-fir, the remainder were western hemlock. Size, moisture content, and weight of the poles are listed in Table 2.

After each charge was placed in the retort, the door was bolted tight. Creosote at room temperature was then pumped in while a vacuum pump evacuated the retort. Steam coils in the retort heated the creosote to the specified temperature in 3 to 4 hours. Water began to evaporate from the wood about two hours after the start. The mixed vapors of water and creosote were conducted through a water-cooled condenser to the drip tanks, where the condensate was collected. Solid condensate, consisting mostly of naphthalene, collected in the condenser, the drip tanks, and the connecting pipes. A vacuum was maintained on the system by an automatically regulated vacuum pump.

The series of charges were boiled at 24-in. Hg. vacuum, or 153 mm. Hg. absolute pressure, at temperatures from 190° to 280° F. Table 3 shows the temperature and duration of boiling of each charge, and also lists the constituents of the condensate as well as the vapor pressures of naphthalene given by International Critical Tables over the range of experimental temperatures.

Theory

In steam distillation, according to Glasstone[2], "A substance virtually immiscible with water and having a high boiling point, can be distilled at a much lower temperature by passing steam through it. The mixture boils, that is, it distills freely, when the total pressure of the two components is equal to that of the atmosphere (above it)".

Thus, if n_A and n_B are the number of mols of the substances in the vapor and they are completely immiscible, the total pressure P is given by:

$$P = p_A + p_B,$$

and the composition of the vapor by:

$$\frac{n_A}{n_B} = \frac{p_A}{p_B}$$

where p_A and p_B are the partial pressures of the two substances in the vapor phase.

To express the ratio of A to B in the vapor in terms of the actual weights W_A and W_B, the quantities n_A and n_B must be multiplied by the respective molecular weights, M_A and M_B hence[2]:

$$\frac{W_A}{W_B} = \frac{M_A n_A}{M_B n_B} = \frac{M_A p_A}{M_B p_B}$$

The composition of the distillate will be equal to that of the vapor, hence:

$$\frac{W_A}{W_B} = \frac{M_A p_A}{M_B p_B}$$

When naphthalene and water are the two substances, the formula may be rewritten:

$$\frac{W_n}{W_w} = \frac{M_n p_n}{M_w p_w} = \frac{128\ p_n}{18\ p_w} = \frac{7.1\ p_n}{p_w} \qquad \text{Eq. (1)}$$

where $\frac{W_n}{W_w}$ is the naphthalene-water ratio of the condensate,

p_n is the partial pressure of the naphthalene in the vapor phase

p_w is the partial pressure of the water in the vapor phase

M_n is the molecular weight of the naphthalene = 128

M_w is the molecular weight of the water = 18

When creosote is being steam-distilled instead of pure naphthalene, as was the case in the experiments here, the partial pressure of the naphthalene in the vapor phase, p_n is determined by its saturated vapor pressure V_n, by its concentration in the creosote, and by the compounds associated with it, which according to Carey[2] reduce its value. Thus the partial pressure in the vapor phase, p_n, equals KV_n where K is a constant determined by the aforementioned factors and V_n is the vapor pressure of naphthalene.

Under the usual operating conditions of a boiling-under-vacuum system, the temperatures are considerably above the boiling point of water at the absolute pressure that prevails. Liquid water, therefore, does not exist in the system, and as a result the steam in the vapor phase is unsaturated and exerts a partial pressure that is less than its saturated vapor pressure.

This may be illustrated by comparing the vapor pressure of water over the temperature range of these experiments with the actual pressure that existed. From 190° to 280° F., its vapor pressure ranges from 9.3 to 49 psi absolute, whereas the total pressure of the system in all experiments was only about 3 psi absolute.

The partial pressure of the water vapor must, therefore, be less than its saturated vapor pressure. Since the partial pressures of the water vapor and the naphthalene equal the total pressure of the system, the partial pressure of water vapor can be determined as the difference between the total pressure and that of the naphthalene vapor, thus:

$$p_w = P - KV_n$$

Inserting this value in Eq. (1), the formula becomes:

$$\frac{W_n}{W_w} = \frac{7.1\ KV_n}{P - KV_n} \qquad \text{Eq. (}$$

Calculations

The series of experiments was [illegible] at six inches (153 mm.) of mercury absolute pressure. Allowing for the hydrostatic head of creosote of 23 mm. Hg., P = 153 + 23 (mm. Hg.), whence:

[2] This equation is confirmed by Glasstone (Glasstone, S. Textbook of Physical Chemistry. Eighth edition, p. 724, eq. 55) and by (Carey, J. S. Distillation. In: Perry, John. H. Chemical Engineers' Handbook. Second edition, p. 1389, eq. 27).

Table 3.—EFFECT OF TEMPERATURE ON NAPHTHALENE—WATER RATIO OF CONDENSATE FOR CHARGES BOILED AT 153 MM. ABSOLUTE PRESSURE

Charge	Duration of boiling hr.	Temp. °F.	V.P. naphthalene mm. Hg.	Condensate: Naphthalene content lb.	Condensate: Water content lb.	Condensate: Ratio $\frac{n}{w}$
43	70	190	11.9	20	137	0.15
46	22	190	11.9	4	20	0.20
44	70	210	18.9	31	113	0.27
48	21	210	18.9	10	34	0.29
49	22	220	23.2	16	36	0.44
52	38	220	23.2	26	59	0.44
45	22	230	29.4	21	47	0.45
47	22	230	29.4	20	43	0.46
50	23	240	37.0	27	46	0.59
51	23	260	55.3	61	63	0.97
53	23	280	80.9	91	66	1.38

Table 4.—NAPHTHALENE-WATER RATIOS AT 153 MM. ABSOLUTE PRESSURE

Temp. °F.	V.P. naphthalene (V_n)	$\frac{W_n}{W_w}$ (calculated)	$\frac{W_n}{W_w}$ (experimental)
190	11.9	0.18	0.15, 0.20
210	18.9	0.29	0.27, 0.29
220	23.2	0.36	0.44, 0.44
230	29.4	0.46	0.45, 0.46
240	37.0	0.59	0.59
260	55.3	0.91	0.97
280	80.9	1.42	1.38

$$\frac{W_n}{W_w} = \frac{7.1\,KV_n}{153 - KV_n + 23} = \frac{7.1\,KV_n}{176 - KV_n} \quad \text{Eq. (3)}$$

To calculate the value of the constant K, substitute the experimental values from Table 3 for 240° F. in Eq. (3).

$$\frac{W_n}{W_w} = 0.59;\ V_n = 37 \text{ mm.}$$

$$\text{Eq. (3) becomes } 0.59 = \frac{7.1\,K\,(37)}{176 - 37K}$$

$$\text{whence } K = .365$$

and Eq. (3) becomes

$$\frac{W_n}{W_w} = \frac{2.59\,V_n}{176 - .365\,V_n}$$

By means of this equation, the calculated naphthalene-water ratios at all other temperatures are tabulated in Table 4 and plotted in Fig. 1.

Discussion

1. The value of the constant K in equation (2) depends on the characteristics of the creosote. Where creosote different from that tested in these experiments is used, and it is desired to calculate the naphthalene-water ratio for any specific conditions, it is necessary to first calculate the value of K as is done in this report.

2. While most of the experiments reported here were performed on western hemlock, charges 43 and 44 (Table 2) were coast-type Douglas-fir. As may be seen, the naphthalene-water ratio for these charges was not significantly different from those of western hemlock. Since the only function of the wood would seem to be to supply the water of the condensate, the results might be expected to apply to any species. It remains to be determined whether the equation is affected by extractives to be found in some species.

Conclusions

1. Each pound of water carries over a fixed amount of naphthalene under specified operating conditions, therefore a green charge causes more naphthalene to accumulate in the system in a given time than does a dry charge.

2. The higher the temperature of the creosote bath of the Boulton process, the higher will be the proportion of naphthalene in the condensate. At 24 inches of vacuum, the weight of the naphthalene in the condensate ranges from 18 per cent to 142 per cent of the water as the temperature is increased from 190° to 280° F. At high temperatures and vacuums, the amount of the naphthalene evaporated increases the possibility of freezing in the lines, which in turn makes control of the operation difficult or impossible.

3. Equation (2) indicates that, the greater the proportion of low-boiling fractions in the creosote, the greater will be the amount that distills off with the water.

4. Equation (2) indicates that the naphthalene content of the condensate is higher when the absolute pressure of the system is lowered (at high vacuum).

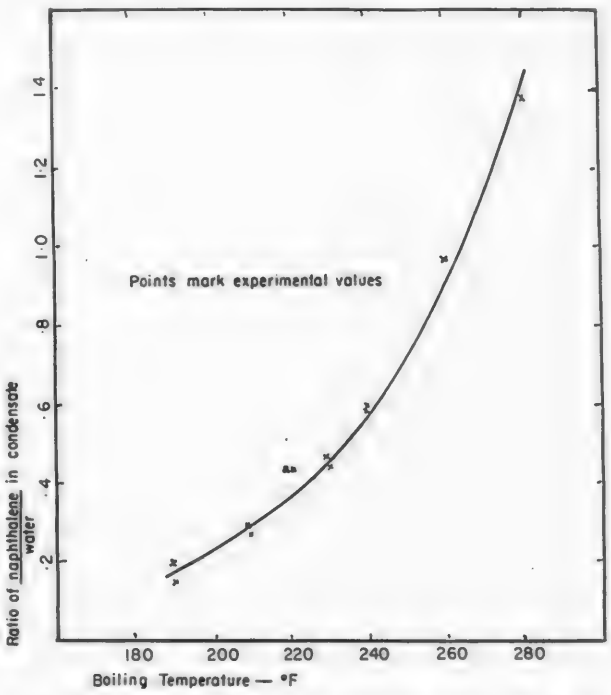


Fig. 1.—Effect of temperature on naphthalene—water ratio in condensate from logs boiled at 6 inches mercury absolute pressure (153 mm.).

Tree Grade Cruising Possibilities from a Study in Second-Growth White Oak[1]

D. P. WORLEY, O. A. SCHMIDT, and A. R. DUHNKRACK
School of Forestry, Pennsylvania State University, University Park, Pa.

In this grading system, trees are graded according to the number of select faces and the diameter at breast height. The error in determining Quality Index for a single tree may be high, but is greatly reduced as the number of trees sampled is increased.

THE RESIDUAL STANDS OF TIMBER left following the heavy cutting practices of the past are generally understocked and of poor quality. This situation has become critical at the present time because premium prices are paid for high-quality lumber, while low-quality lumber seldom, if ever, pays its way through the sawmill.

A favorable proportion of lumber in the upper grades can only be obtained from high-quality trees. For this reason, foresters are finding that timber quality is every bit as important as timber volume in managing a forested tract of land. Some tree quality grading systems have been developed based on log quality grades (4)[2]. Generally, these grading systems are too time-consuming for a forester to use in the course of normal timber cruising procedure, and too complex for an untrained timber operator to use. Much timber quality appraisal is done by sawmill operators who use an ocular estimate that is anything but objective. For an objective timber quality system to be widely accepted, it must be stated as simply as statistical accuracy permits.

In an attempt to develop such a system, a tree grading project was initiated by selecting 45 white oak trees for analysis. Any tree grading system based on data from 45 trees of a single species in a single locality can not, of course, produce specific tree quality figures that can be generally applied. Such a study can be valuable by adding to our knowledge of methodology and aid in placing tree grading systems in better perspective. The test trees were selected according to the grading system described by Campbell to give an equal number between Grade A, Grade B, and Grade C trees (4). Care was also taken in the selection to see that a wide range of diameters were present (10 to 24 inches) and that there was wide variation in the number of surface defects appearing on the tree. Each tree was measured to determine its total and merchantable height and diameter breast high (Dbh). Additional information recorded on a tree diagram showing the four possible faces included all surface defects plotted in their proper orientation on the tree boles. The trees were felled, and the above procedure was repeated on the felled trees. The trees were bucked into logs of different lengths according to optimum bucking principles designed to permit the sawmill operator to recover the highest lumber grades from each tree. The logs were trucked to the University sawmill, where they were carefully sawn to obtain the best grade of lumber possible. The volume of lumber in each grade was summed for each tree to be used in the subsequent tree grading analysis.

In working the data for the trees, an attempt was made to compare this system of grading with that used by Campbell (4). Because of the differences in approach, no correlations can be drawn. This is readily explained in the fact that Campbell used the grade of respective logs within the tree, whereas the system being described uses a formula based on diameter and number of select faces. The Campbell System indicates log grades, while the other method establishes the percentage of No. 1 common or better lumber in the average tree.

Close inspection of the data thus collected led to conclusions similar to those developed by other workers in the field (5). It appeared that the percentage of lumber recovered from a tree in any particular grade or group of grades was in some way correlated to the size of the tree and an expression of the orientation of the surface defects. Generally higher proportions of the top grades of lumber were recovered as tree diameter increased and the number of surface defects decreased.

It was decided to correlate individual expressions of tree size and surface defect orientation with the percentage of No. 1 common or better lumber. A regression type of analysis was used, which led to an equation in the form of $Y = a + bX$, where Y equals the percentage of No. 1 common or better lumber and X equals the expressions of tree size or surface defect orientation. Later regressions in the same form were to be calculated with combinations of tree size and surface defect expressions for X.

The independent variables for tree size used were merchantable height in logs and diameter breast high. The independent variable describing surface defects became number of select faces in the butt 16-foot log. A select face in this study is defined as one that has only one visible defect in the lowest 16 feet of tree bole.

Restricting the orientation of surface defects to the butt log was done because discrepancies were noted between the location of surface defects when measured on the standing tree and when precisely located on the felled tree. It was found that an average of 10.8 defects per tree were either missed or mislocated when measured in the standing tree. Of these, 10 were

---

[1] Authorized for publication August 9, 1957, as paper No. 2184 in the Journal Series of the Agricultural Experiment Station.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Authors: David Worley received his BSF from Syracuse University and his MF from Duke. Formerly Assistant Professor of Forestry at Penn State, he became affiliated with the Central States Experiment Station, Berea, Kentucky in 1957.

Orvel Schmidt received his MF from the University of Michigan. He was with the Wisconsin Conservation Department and the Forestry Department of the Nekoosa-Edwards Paper Co., and is now Associate Professor of Forestry at Penn State.

Alan Duhnkrack received a BS in agriculture from Rutgers and an MF from Penn. State. This paper is connected with his thesis work. He is currently employed by the U. S. Forest Service, Allegheny National Forest.

Table 1.—SUMMARY OF REGRESSION ANALYSES EXPRESSING LUMBER GRADE RECOVERY AS A FUNCTION OF TREE CHARACTERISTICS THAT CAN BE MEASURED IN THE STANDING TREE

	Independent variables	Equation[1]	s_{YX}	Correlation coefficient
X_1	Dbh in inches	$Y = -18.51 + 3.16X_1$	13.37	0.49
X_2	No. of Logs	$Y = 21.12 + 4.78X_2$	15.25	0.12
X_3	No. of Select faces to 4	$Y = 8.77 + 9.32X_3$	10.06	0.76
X_4	No. of Select faces to 3	$Y = 5.47 + 11.64X_4$	9.53	0.78
X_5	Dbh x No. of Select faces to 3	$Y = 7.31 + 0.66X_5$	9.19	0.80

[1] Y equals the percentage of No. 1 common or better lumber recovered from a tree.

Table 2.—NO. 1 COMMON OR BETTER LUMBER GRADE RECOVERY FROM TREES OF DIFFERENT CHARACTERISTICS

Dbh in inches	Per cent No. 1 Common or Better lumber according to number of select faces			
	0	1	2	3
10	7.3	13.9	20.5	27.1
12	7.3	15.2	23.2	31.1
14	7.3	16.6	25.8	35.0
16	7.3	17.9	28.3	39.0
18	7.3	19.2	31.1	43.0
20	7.3	20.5	33.7	46.9
22	7.3	21.8	36.4	50.9
24	7.3	23.2	39.0	54.8
26	7.3	24.5	41.6	58.2
28	7.3	25.8	44.3	62.8
30	7.3	27.1	46.9	66.7

found to be in the upper portion while an average of only 0.8 defect discrepancies were noted in the butt log.

The above findings would indicate that an analysis based on butt-log characteristics is desirable. This need not be considered a weakness in a tree grading system, because the bulk of the volume is generally found in the butt log and the highest quality lumber comes from this area. It must be remembered too that simplicity of application was to be incorporated into the system. For this reason, earlier specifications used in butt-log grading computed for all the single variable were discarded as being too complicated, in favor of the simpler definition for select face described above. Table 1 summarizes the regressions computed for all the single variable equations and the one multiple variable equation which produced the best results.

It is interesting to note from Table 1 that better results were obtained when three select faces were used than when four were used. This is closely analogous to disregarding the poorest face in favor of grading the second-poorest face, as is done in log grading (2).

The regression with X_5 was finally selected as the most successful expression. This expression forms a logical basis, because lumber grade recovery can be expected to vary directly with either Dbh or number of select faces. The equation expresses these relationships with due weight given to both variables. Other equations in which they were added together or used separately did not produce nearly so good a result. A table of values for Y was computed for different numbers of select faces and Dbh's, and is shown as Table 2.

A recognized and recently accepted indicator of tree value is the quality index (QI). The QI is obtained by expressing the value of each grade of lumber as a proportion of the value of No. 1 common lumber, multiplying each grade recovery by the proportional price for that grade, and summing the resulting figures to obtain a single figure that describes the proportional value of the tree. The actual value of the tree can be determined from the (QI) at any time by multiplying the QI by the volume of lumber in the tree and the actual price of No. 1 common lumber (1).

To develop a quality index, regressions were computed for the percentage grade recovery of each lumber grade with X_5 as the independent variable. These regressions are summarized in Table 3.

A superior regression was later obtained for No. 2 common grade lumber by using Y which makes the new expression $Y = 25.3$.

When price relatives from a recent article by Beazley and Herrick (3) of FAS = 1.4, Sel and No. 1 Com. = 1.0, No. 2 Com. = 0.6, and No. 3 Com. = 0.4 are used, the QI can be calculated for various values of X_5. For a 20-inch white oak with two select faces, X_5 becomes 40 and the corresponding lumber grade recoveries computed from the equations in Table 3 become FAS = 10.86 per cent, Sel = 7.13 per cent, No. 1 Com. = 14.90 per cent, No. 2 Com. = 25.04 per cent, and No. 3 Com. = 41.67 per cent. By multiplying the individual lumber grade recovery by the corresponding price relative, the QI becomes 69.

Example of QI determination:

FAS	= 10.86 x	1.4	= 15.20
Sel	= 7.13 x	1.0	= 7.13
No. 1 Com.	= 14.9 x	1.0	= 14.90
No. 2 Com.	= 25.04 x	0.6	= 15.02
No. 3 Com.	= 41.67 x	0.4	= 16.67
			68.92

This estimate of QI is subject to error. Actually, the error of estimate of lumber grade recovery and any error in the price relatives combine to create the error of the quality index. An equation that expresses QI has been written as follows (1):

$$QI = \%FAS\ (PR_{FAS}) + \%Sel\ (PR_{Sel}) + \%No.\ 1\ Com. + \%No.\ 2\ Com.\ (PR_{No.\ 2\ Com.}) + \%No.\ 3\ Com.\ (PR_{No.\ 3\ Com.})$$

Where PR is the price ratio of the value of various grades to the value of No. 1 common lumber.

The error in QI will be equal to the sums of the errors of the individual products as shown below:

$$S_{QI} = \sqrt{(\%FAS)^2\ (S_{PR_{FAS}})^2 + (PR_{FAS})^2\ (S\%_{FAS})^2 + \text{------} + (\%No.\ 3\ Com.)^2 (S_{PR_{No.\ 3\ Com.}})^2 + (PR_{No.\ 3\ Com.})^2\ (S\%_{No.\ 3\ Com.})^2}$$

The error of the QI for the example above can be calculated as follows: First, if an error of 0.2 is hypothesized for all the price ratios except for No. 1 common, and the standard errors of lumber grade recovery computed in Table 3 are used, one has the necessary data for the computation of S_{QI}. It is found to be $\pm$ 18 so that the complete expression for the QI for the sample tree is 69 $\pm$ 18.

Variation of this magnitude makes the QI determination for a single tree misleading, but an average QI for a group of trees can be obtained with reasonable accuracy. By incorprating a column for number of select faces into a standard cruise form, the accuracy of an average QI for the trees cruised can be increased by increasing sample size, as shown in Table 4.

These results indicate that, with the application of the grading rule, it is possible to predict the quality index

Table 3.—SUMMARY OF REGRESSIONS EXPRESSING PER CENT LUMBER GRADE RECOVERY FOR EACH LUMBER GRADE

Lumber grade Y	Equation X_5 = D.b.h. x No. of Select Faces	s_{YX}	r	Significance
FAS	$-3.14 + 0.35X_5$	7.13	0.67	1%
Sel	$2.33 + 0.12X_5$	5.80	0.37	5%
No. 1 Com.	$8.10 + 0.17X_5$	8.17	0.34	5%
No. 2 Com.	$30.24 - 0.13X_5$	8.83	0.23	N.S.
No. 3 Com.	$62.87 - 0.53X_5$	13.71	0.57	1%

Table 4.—NUMBER OF TREES THAT SHOULD BE MEASURED TO DETERMINE QI WITHIN CERTAIN LIMITS OF STANDARD ERROR

Error of the average QI	Number of trees to be measured
1.0	400
2.0	100
5.0	16
10.0	4

of a lot of trees within reasonable limits.

Summary

In white oak, it appears to be possible to determine the grade recovery of lumber in a tree by the use of the number of select faces and diameter of a tree.

The equation $Y = 7.31 + 0.66X_3$, in which X_3 = Dbh times No. of Select faces to 3, shows an accuracy of ± 9.19 per cent on a sample of 45 trees. The use of QI to determine the value of a tree is accepted by many evaluators of standing timber. In determining the QI value of a single tree, the error may be ± 18. With a sample of 100 trees, however, the standard error can be reduced to ± 2.

The use of tree grade and quality index can become a very important tool for the forest timber cruiser, forest manager, timber buyer, or any other person in the field of forest evaluation.

Literature Cited

1. Anon. 1952. Proceedings of a symposium on a standard hardwood quality index. The Purdue Agr. Expt. Sta., Lafayette, Ind.
2. Anon. 1953. Hardwood log grades for standard lumber. Forest Prod. Lab. No. D1737.
3. Beazley, Ronald I., and Allyn M. Herrick. 1954. Lumber price relatives. Purdue Univ. Sta. Bul. 610.
4. Campbell, R. A. 1951. Tree grades, yields, and values for some Appalachian hardwoods. U. S. Forest Service Southeastern Forest Exp. Sta. Paper 9.
5. Herrick, David E., and Willard L. Jackson. 1957. The butt log tells the story. Sta. Note 102, Central States Forest Exp. Sta., Columbus, Ohio.

Reducing Heat Distortion in the Knife and Pressure Bar Assemblies of Veneer Lathes[1]

A. O. FIEHL

Ottawa Laboratory, Forest Products Laboratories of Canada, Ottawa, Ontario

Heat transmitted from hot logs and veneer causes unequal expansion in the knife, bar, and carriage of the lathe. The horizontal and vertical openings thus become non-uniform and faulty veneer is cut. Distortion can be reduced to a negligible amount by heating the lathe uniformly or, better, by dissipating the heat with water cooling elements.

DISTORTION IN THE KNIFE AND BAR assemblies of veneer lathes, through thermal expansion, often results in the production of faulty veneer. It was believed that if some means of preventing this heat distortion could be developed, the regularity of the veneer quality would be appreciably increased, and the lathe operator's work would be simplified. The value of research data, which provides precise lathe settings for cutting different species, also would be greatly enhanced. Investigations were carried out at the Ottawa Laboratory of the Forest Products Laboratories of Canada to determine the nature and extent of this distortion. The results of these studies are presented herein, along with details of a technique developed for reducing the distortion to a negligible amount.

Veneer lathes are machines designed for precision work. Their primary settings can be made with an accuracy of one thousandth of an inch or a few minutes of angle. Unfortunately, when hot logs are peeled (130° to 200° F.) the heat transmitted by the log and veneer to the knife edge, the bar edge, and the surrounding metal of the lathe carriage causes these parts to heat non-uniformly. The resulting thermal expansion causes distortion in the knife and bar assemblies. This distortion takes the form of a bow, which changes appreciably and non-uniformly the horizontal and vertical openings (gaps) between the knife and bar, two of the most important adjustments of the machine. Unevenness in these gaps leads to the production of faulty veneer.

To prevent the narrowing, through heat distortion, of the horizontal and vertical gaps at the center of the lathe, some lathes have been equipped with a yoke, which is mounted on top of the nose-bar frame. The purpose of this attachment is to bend the nose bar frame by means of a heavy screw, and so compensate for the narrowing of the gaps. The corrections provided in this way are very approximate, however, and the manual adjustment of the screw absorbs part of the lathe operator's time and attention. Often these adjustments are not made as frequently as they are needed.

Nature and Extent of Lathe Carriage Distortion

The distortion appearing in the lathe carriage when hot logs are peeled

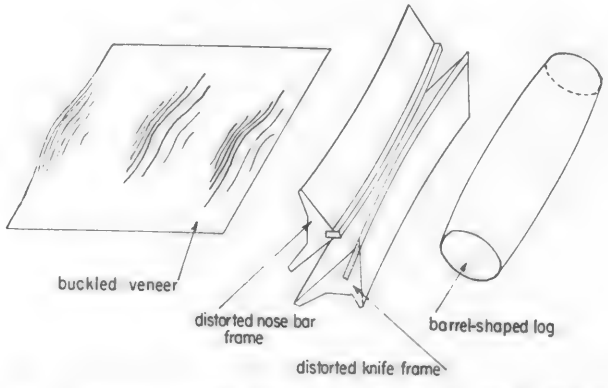


Fig. 1.—Distortion of lathe carriage caused by heat, and its effect on log and veneer. (Exaggerated for purpose of demonstration.)

[1] A contributed paper (December, 1957) from the Forest Products Laboratories of Canada, a Division of the Foresty Branch, Department of Northern Affairs and National Resources.

The Author: A. O. Fiehl graduated in Forest Engineering and Wood Technology from the Swiss Federal Institute of Technology (Zurich) in 1945. He worked in civil engineering for two years, then came to Canada and worked as a logging supervisor for eight years before he joined the staff of the FPL of C, where he specialized in research on veneer and plywood.

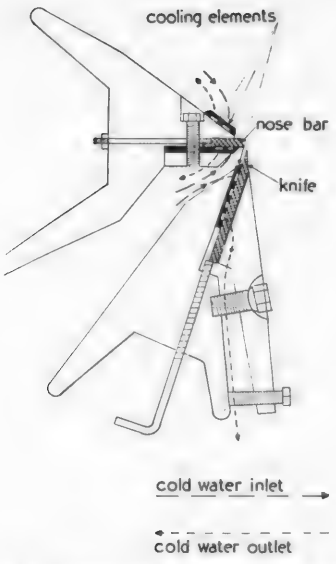


Fig. 2.—Section of the lathe showing the position of the cooling elements.

always takes the shape of a bow that tends to close the horizontal and vertical gaps more in the center of the lathe than at the ends (Fig. 1). This bowing is caused by uneven longitudinal expansion resulting from nonuniform heating of the lathe carriage. The knife and bar edges are quickly heated to a temperature approaching that of the log, and this heat is slowly diffused through the carriage. Temperature measurements, made with thermocouples at seven different points on the central section of the carriage (Fig. 3), indicated that when logs heated to 140° F. are cut for 25 minutes, the increase in temperature exceeds 20° F. at points 1 and 6 (3 inches away from the knife and bar edges), but that the heat increase barely reaches 5° F. at the furthest edges of the carriage. Because the temperature of the metal decreases with the distance from the log, the longitudinal heat expansion is more pronounced at the knife and bar edges than at the bottom of the knife frame or at the back of the bar frame. This difference of elongation causes these two frames to bow slightly in the direction of the hottest parts, thus closing unevenly the vertical and horizontal openings.

Measurements of the amount of distortion occurring in a 52 inch lathe, when cutting hot logs, were made by two different methods. The first method involved attaching troughs (in which hot water could be circulated) to the knife and bar faces. In this manner, the heating action of a hot log could be reproduced. Four dial gages were mounted on a stand resting on the floor to measure both horizontal and vertical movements of the knife edge and nose bar tip at the center of the lathe. Water at a temperature of 160° F. was circulated through the troughs for a period of 10 minutes, during which time the movements of the nose bar and knife edges were noted. The average movements as recorded in this manner were as follows:

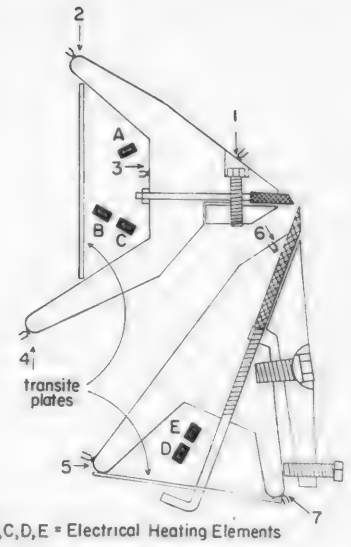
Horizontal movement of the nose bar towards the lathe spindles	.006"
Horizontal movement of the knife tip towards the lathe spindles	.060"
Vertical upward movement of the nose bar	.001"
Vertical upward movement of the knife tip	.008"

The net result of these movements was a closing of the horizontal gap by 0.006 inch and of the vertical gap by 0.007 inch.

With the second experimental procedure, the vertical and horizontal gaps were measured with lathe setting instruments before the log heated to 140° F. was peeled. At the end of the cut (after 12 minutes), the gaps were measured again, and both the vertical and horizontal gaps were found to have decreased by 0.005 inch at the center of the lathe, and to have remained unchanged at the ends. These movements were also measured under production conditions on 110-inch lathe cutting yellow birch logs heated to 160° F. The narrowing of the vertical gap was found to be as much as 0.020 inch and that of the horizontal gap as much as 0.010 inch.

Effect of Narrowing Gaps on Veneer Quality

Because of the narrowing of the horizontal and vertical gaps towards the center of the knife, the veneer tends to be cut thinner at the center of the log than at the ends. As a first result, the log diameter decreases faster at the ends than in the center and the log develops a slight barrel shape (Fig. 1). At this stage, the veneer sheet produced after each turn of the log is longer in the center than at the edges, which results in bucklings of the veneer. If the veneer is reeled directely from the lathe it will appear to the lathe operator like a concave ribbon instead of a flat one. When moving on a conveyor, the veneer will be buckled in the center and flat at the edges. Such veneer is difficult to dry flat, and its irregular thickness is a potential source of trouble in both the jointer and in the press. In addition, and because of the impossibility of setting the lathe properly, the quality of the veneer surface cannot be closely controlled. To prevent overcompression of the veneer at the center of the lathe, the horizontal gap must be set larger than the optimum value. As a consequence, there is not enough compression at the veneer edges to prevent the formation of veneer roughness and even raised fibers, particularly when logs with irregular grain direction are being cut.



A, B, C, D, E = Electrical Heating Elements
1 to 7 = Thermocouples

Fig. 3.—Disposition of the five electric heating elements used for heating the knife carriage, and seven thermocouples for measuring temperatures at various points on the carriage.

Means of Reducing Heat Distortion

Two different methods of reducing the thermal distortion of the lathe carriage were experimented with at the Ottawa Laboratory. Both were aimed at decreasing the temperature differential between the various parts of the carriage, and both proved efficient in reducing distortion to a negligible amount.

The first method consisted of preheating the lathe carriage with electric heating elements (Fig. 3) to 130° F. (the highest temperature at which the lathe could be touched by the operator without serious discomfort). In this manner it was possible to reduce considerably the temperature differences in the carriage during the peeling process, and hence to practically eliminate the undesirable distortion. Although this method gave good results, it was believed that working with a machine heated to 130° F. would be undesirable from the point of view of the lathe operators. Therefore, an alternate method of keeping the lathe carriage cool was also tried.

To keep the knife and nose bar as cool as possible, and at the same time prevent the heat of the log from diffusing into the lathe carriage, three cooling elements were prepared and mounted on the lathe as shown in Figs. 2 and 6. For this purpose, ¼-inch thick cold rolled steel bars were grooved so as to permit cold water circulation. A design of the knife cooling element is shown in Fig. 4.

The knife-cooling element was clamped between the knife and the knife frame with the machined surfaces of these two parts giving practically a water-tight joint. Another element of a similar design was placed under the nose bar and clamped between the nose bar and its frame. Finally, one smaller element was fixed with screws to the bar frame directly above the nose bar and made water-tight with rubber gaskets.

Because the design of some veneer lathes could prevent the insertion of a cooling element directly under the nose bar, further tests were made in which this element was placed under the plate holding the nose bar. With these elements installed, the lathe settings were adjusted with precision, and logs—heated throughout to 140° F.—were peeled for 25 minutes while water at 70° F. was circulated through the elements. The horizontal and vertical gaps were then measured again and found to have decreased by less than one thousandth of an inch, as compared to five thousandths or even more when the lathe was not equipped with cooling elements.

When the lathe is designed for a slotted knife, the plan of the knife-cooling element is more complex. Preliminary experiments with an element grooved as indicated in Fig. 5 showed that excellent circulation of water is obtained with this type of grooving.

Conclusion

The distortion caused by heat that appears in the veneer lathe carriage when hot logs are being cut, and which not uncommonly leads to the production of faulty veneer, can be reduced considerably by preventing the heat from the logs from diffusing into the carriage. Experiments on a laboratory lathe have shown that the closing of the vertical and horizontal gaps between the knife and nose bar could be reduced from five thousandths of an inch on a standard 52 inch lathe to less than one thousandth on the same lathe equipped with water cooling elements. Although no experiment was made on larger lathes, it can be expected that the use of similar elements would considerably reduce the closing of the gaps (up to 20 thousandths of an inch) that occur on these machines when they cut heated logs.

Cooling elements such as those used in the experiments can be readily produced and installed on a lathe. Such a procedure can be followed in modifying lathes currently in use. A more satisfactory arrangement in the case of new lathes being manufactured would be to have suitable cooling devices built into the lathe as part of the original equipment. The provision of a means such as this to prevent the distortion that occurs when heated logs are peeled would do much to improve the quality of the veneer produced.

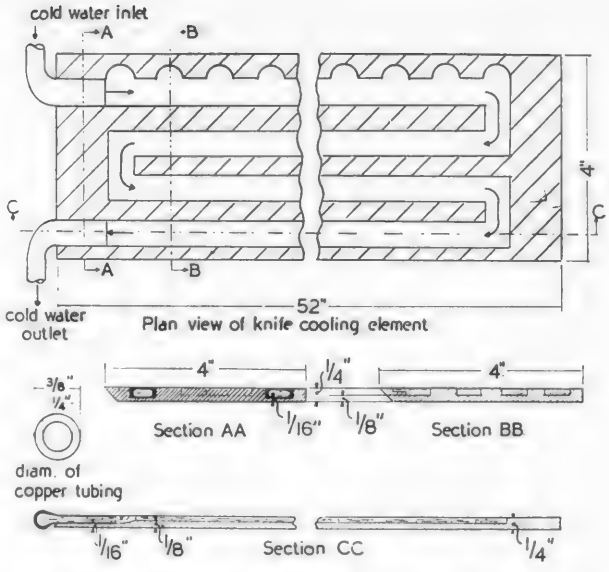


Fig. 4.—Design of the knife-cooling element for a plain knife.

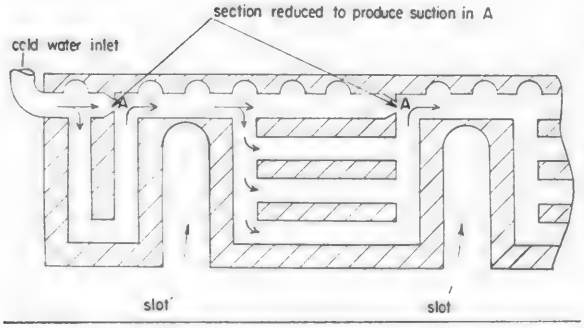


Fig. 5.—Design of the knife-cooling element for a slotted knife.

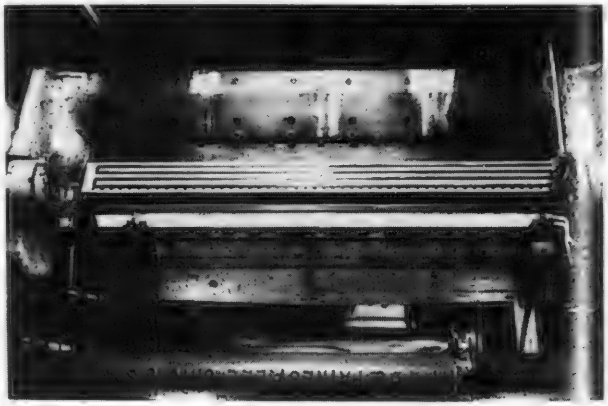


Fig. 6.—This view of the laboratory lathe (knife removed) shows the knife-cooling element and the pressure bar upper cooling element. Both are painted white.

The Fork Lift Truck for Handling Forest Products[1]

JAMES J. BEACH, JR.
Regional Sales Manager, Silent Hoist & Crane Co., Brooklyn, New York

The fork lift truck is a counter-balanced machine that supports the load with its own weight. Factors such as working capacity, lift heights, free lift, ground conditions, steering axle, machine balance, engines, and special attachments are discussed.

PRACTICALLY EVERYONE in the lumber business has had experience with some type of material handling equipment. In view of the ever-increasing costs of labor, it is important that management plan to use the most efficient methods if they hope to be competitive in today's lumber markets. Fortunately for most, mechanical handling of lumber has made possible both better prices and better service.

Proper application of *all* types of equipment will in general result in a more effective handling system, but possibly the most revolutionary changes have been brought to the techniques of lumber handling with the introduction of the fork lift truck. Now, one man and a lift truck can handle in minutes what formerly required a crew of men and hours of drudgery.

The purpose of this paper is to discuss briefly the types of fork trucks and important considerations in the selection of suitable equipment for lumber handling.

What Type of Fork Lift Truck?

The answer to this particular question is determined by a number of factors, including:

Type and size of load to be handled.
Working space available.
Whether indoor or outside yard application.
If out-of-doors, type of ground condition.

This discussion will be confined to lift trucks of 6000 lbs. capacity and larger, which in the lumber business are mostly pneumatic-tired machines and primarily designed for outside operation.

Working Capacity

The fork truck is basically a counter-balanced machine. That is, it supports a load with its own weight and tends to pivot about the front axle. It suffices here to point out that the weight of a package of lumber, the further the center of gravity of the load from the truck axle and, consequently, the carrying capacity will be proportionately reduced. For this reason, the capacity of any model can only be designated properly when a distance from the axle, or more conveniently the heel of the fork, is included (such as 15,000 lbs. at 24 inches or 30,000 lbs. at 36 inches from the heel of fork).

The load arms, or more technically the fork tines, are usually adjustable laterally on the moving lift carriage. This lift carriage, by the way, is often referred to as the apron. Fork adjustment is important for different size packages or lumber lengths. Where longer load lengths are regularly carried, extra-wide aprons can be furnished for increased support and better carrying stability.

The length of the individual fork tines is determined by the width of the load to be carried. Where occasional wider packages are handled, the fork tines can readily be equipped with fork extensions or slippers. These slippers are fitted over the standard tines to provide the desired increased fork length. The standard fork tines are one-piece alloy forged steel, while the extensions are plate weldments and less rigid, particularly near the tip since they are not supported by the shorter tines over the entire length. Usually, the extensions are designed for an evenly distributed load such as packaged lumber; they are not well suited to log handling or any similar operation that require a prying action.

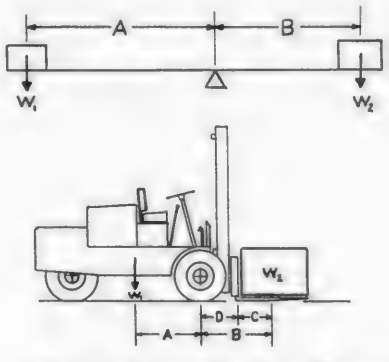


Fig. 1.—The payload of a fork lift truck is determined by the simple physics of a lever.

Fork Lift Heights

Usually, fork truck manufacturers have available standard lift heights up to approximately 18 ft. at the full working capacity of the fork lift truck.

It is not considered good practice to travel with loads elevated more than a few feet above the ground, but there are cases where longer lumber lengths and narrow aisles combine to make travel with loads high in the air a necessity. Above all, truck speeds should be kept to a minimum; at the higher lifts, working loads should be considerably less than the rated capacity of the machine.

On occasion, special fork lift trucks have been constructed to provide for lift heights of over 35 ft., but here again the fork capacity at the higher lifts is only a fraction of the full rated capacity of the equipment.

Free Lift

This applies to a unique lifting mast assembly that permits the raising of the fork carriage with no increase in the all-over height. Free lift is one of the many special features that are available even in the 15 to 20 thousand lb. capacity fork trucks that are called on to work under sheds where headroom is at a premium.

Ground Conditions

Ground conditions play an important part in the success of any fork truck operation. Generally, an improvement in the ground conditions will result in a corresponding increase in fork truck efficiency. The ideal condition would be a yard entirely paved, but this, of course, is not a requisite for effective handling of lumber with fork trucks.

Even with a fully paved yard, there are pitfalls. Relatively smooth driving surfaces very often lead to high travel speeds and shortened chassis life. The majority of heavy-duty fork trucks are unsprung vehicles, and a large percentage of the chassis and tiering frame wear is a result of road shock. It is rarely possible to distort a properly designed chassis or tiering frame without adding considerably more

[1] Presented at the Fall Meeting of the Northeast Section, FPRS, held Oct. 31–Nov. 1, [illegible] in New York, New York.

counterweight than furnished as original equipment. Experience has shown that road shock is one of the chief causes of chassis failure. Good roadway maintenance and controlled travel speeds are two of the more important factors in insuring trouble-free lift truck operation.

There are areas where heavy frosts and resulting spring mud make it almost impossible for full time use of the conventional fork lift truck. For these conditions, there are available high flotation fork trucks that feature large tires, high underclearance, and heavier gear train. They may cost more initially, but by the same token these trucks will work easily on terrain formerly considered impassable for other equipment. Larger tires and longer wheelbase require a little more space for maneuvering, but lumber handlers who have, poor ground conditions consider this a small price to pay for year-round operation.

The Steering Axle

Ordinarily, the so-called caster-type steer, that is with the rear steering wheels relatively close together, permits possibly the best turning radius for any given wheelbase. The overall handling characteristics are excellent for the average yard condition, although it has some limitations where severe mud conditions are regularly encountered. The wide steering axle, although not quite as maneuverable as the caster-type steer, tracks well in the wake of the larger traction wheels, and thus requires less power in plowing through mud, sand, or snow.

Machine Balance

Possibly one of the most important characteristics for a successful lift truck operation in soft ground is the unloaded weight distribution of the unit. As most fork truck operators soon find out, there is no special trick to handling a fork truck on slippery ground when heavily loaded, but very often they get in trouble once the load has been put down. In fork lift truck chassis design, we strive for approximately a 50–50 weight distribution on the standard trucks . . . and better than 50 per cent of the total weight on the traction wheels for those units designed for soft or slippery terrain. In many cases, to achieve the desired weight distribution, extra weight is included in the vicinity of the drive wheels in the form of large, solid wheel castings or heavy fenders. This extra machine weight adds little to the lifting capacity, but is often the difference between go and no-go when slippery ground conditions are encountered.

Engines

Although we are accustomed to hear of horsepower ratings of up to 300 under the hood of a conventional automobile, in the manufacture of fork lift trucks we try to be more realistic.

Power is a function of speed and engine torque, and since travel speeds are relatively slow, big gear reductions can be used to get enough power actually to spin the traction wheels with industrial engines that have a rating of from 90 to 125 HP. This is the common power plant for fork trucks in the 7½ to 12 ton category. The addition of more powerful engines would place excessive requirements on the power gear train, and in general unnecessarily waste fuel. The less-complicated industrial six cylinder engines usually result in less maintenance and are most popular with equipment users.

Ordinarily, the standard transmission of the fork truck requires equal travel speed in both the forward and reverse directions. Incorporating provisions for up to four speeds forward and four reverse, the fork truck transmission is usually actuated with two levers, one for selection of the speed range, and the other for direction.

A significant development in fork lift truck transmissions has been the addition of the *hydraulic fluid coupling*, which adds appreciably to engine clutch life, and is well suited to the start-stop-reverse maneuvers typical of fork lift truck operation. In addition to increased clutch life, this fluid linkage provides for *cushioning* effect that does much to minimize road shock that might otherwise damage transmission and vital engine components.

The fully automatic transmission eliminates the engine clutch pedal entirely, and has proven excellent in high cycle production type operation. There are available fully automatic transmissions that appear to stand up under tremendous punishment, but as yet there are only relatively few of these clutchless fork trucks in lumber handling, with no conclusive data on the service life that can be anticipated.

Many experienced fork truck operators consider an ideal compromise to be the fluid coupling or torque converter with conventional four speed transmission that results in minimum clutch wear, yet full operator travel control.

Pneumatic-tired Fork Lift Truck versus Crawler Tractor

Soft terrain has long been the exclusive domain of the crawler tractor. More and more, these operations are being taken over by the large pneumatic-tired machines with high underclearance. Of course, they will not go everywhere a crawler tractor has been operating, but for all practical purposes, they will do an effective handling job, and have certain other advantages that have added considerably to their all over popularity.

In addition to the lower initial cost,

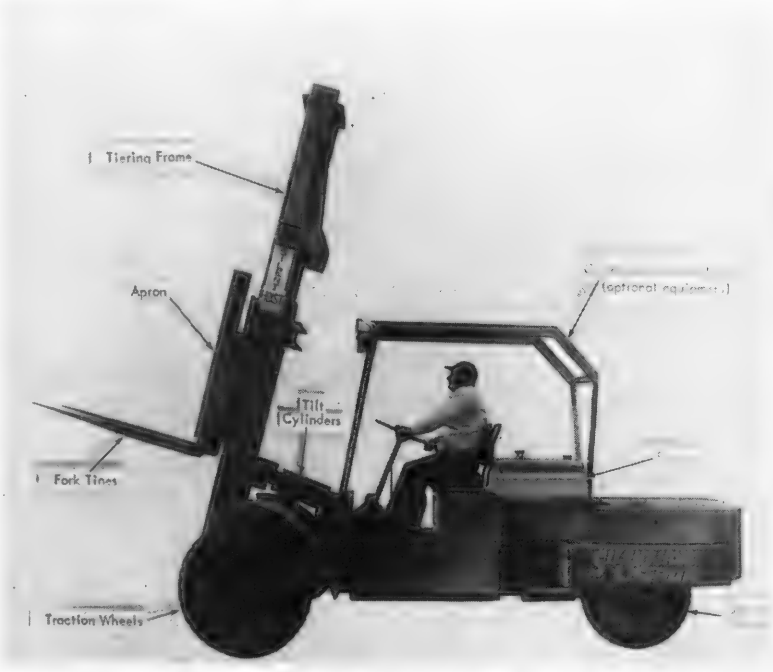


Fig. 2.—A heavy-duty fork truck, 15,000 pounds capacity, especially designed for lumber handling.

Fig. 3.—High-flotation fork truck, 20,000 pounds capacity, features extra-large tires, high underclearance, is designed for year-round operation on poor ground conditions.

Fig. 4.—Compact fork truck, 6,000 pounds capacity, combines high lifting capacity with sharp maneuverability.

the pneumatic-tired machines will: travel faster and maneuver easily; are simpler to maintain; have higher carrying capacity with greater fork lift height; plus the fact that the large pneumatic tires tend to smooth out the soft ground rather than claw it up as will the crawler tread.

Special Attachments

By far, the majority of fork lift trucks in lumber service have conventional lifting carriage with manual spacing of fork tines. There are a number of excellent power attachments available for the lifting carriage that under certain conditions can add appreciably to the efficiency of the fork lift truck operation.

One of the original and most popular attachments is the side shifter, a power device for lateral movement of the entire fork carriage, ordinarily limited to six inches either side of the center, or a total travel of 12 inches. The side shifters are most useful in close stacking of large number piles typical of dry-kiln loading.

In some cases, the side shifter is combined with a device for partial rotation of the apron, known as a sloper. This is a common accessory in areas where lumber is stacked outside for air drying and a slight slope to the pile will insure adequate drainage. The power sloper also compensates for any slight natural grade in the storage yard.

The original side shift is again combined with another interesting development that permits a pivoting of the apron in the horizontal plane sometimes up to ten degrees either side of center; this power movement can be effectively used in more efficient lumber handling in narrow aisles.

Either lumber or log loads are readily handled when the lift truck is furnished with a tiering frame that will tilt up to 20 degrees forward. The extra tilt digs into the log pile when feeding the mill but does not affect the handling of finished lumber.

There are endless variations of this type of special attachment limited only by the imagination of the user. When considering any of these accessories it is important to have a definite requirement, since otherwise they take the form of unnecessary gadgets that exact the following penalties:

(1) Decrease the carrying capacity, usually from 10 to 15 per cent.

(2) Unnecessary added maintenance.

(3) Restricted operator visibility.

(4) While often helping the less experienced operator, they are not always a necessity for the skilled lift truck handler, and in fact they might well impede the development of a good fork truck operator.

Maintenance

Fork truck manufacturers build a machine that when necessary is capable of round-the-clock operation. Rain or shine, the heavy-duty lift truck is designed to be one of the most dependable handling tools, and, in fact, a vital business link. If peak operating efficiency is to be maintained, regular care and a definite preventive maintenance program must be followed. Ordinarily the distributor has available factory-trained service men for this type of work.

First, a good operator is a must. A good operator is not just a man who can quickly handle large quantities of lumber, but more important, one who respects his equipment. He is a man who does not continually ride the clutch, spin the traction wheels with every start, or clash the gears on shifting. In other words, he should have the good working habits that make for common sense in the all-over handling of equipment.

Breakdowns are costly, and even the most rigid adherence to a complete maintenance schedule cannot overcome the shortcomings of a careless operator.

Pallets Play an Important Part in Materials Handling[1]

WILLIAM H. SARDO, JR.

Executive Vice President, National Wooden Pallet Manufacturers Association, Washington, D. C.

Wooden pallets for materials handling have come into their own since World War II and the advent of the fork-lift truck. Sixteen advantages of a good palletization program are listed, along with design requirements that should be specified and rules for a pallet repair program.

THE INCREASING USE OF WOODEN PALLETS since World War II has been one of the outstanding post-war developments in the American lumber industry. The pallet, which had its birth in the mid-1930's, did not achieve any major use until the military services discovered its value as a means of speeding the warehousing, handling, and delivery of supplies during World War II. It was the working combination of the fork-lift truck and the wooden pallet, that created the "cubic concept" of modern warehousing, which permits the use of air space as well as floor space in storage areas and transportation vehicles.

Savings in labor and handling costs resulting from palletization average between 40 and 45 per cent, which when coupled with its many side benefits explain why the growth of the wooden pallet manufacturing industry over the past five years has been so phenomenal. This industry, which economists say is the fastest-growing segment of the lumber industry, produced more than 49,700,000 units valued at approximately $125,741,000 in 1956. It consumed about 1,232,500,000 board feet of lumber during the past year. At least 75 per cent of this lumber was hardwood species, with the balance accounted for by softwoods.

Modern materials-handling equipment and pallets go hand-in-hand. There is a market for pallets wherever a fork-lift truck or other mechanized equipment is used to move packaged or bulk goods from one place to another.

Pallets have in recent years ceased to be limited to intra-plant use. Throughout our nation today, thousands of companies from large industrial plants and warehouses to very small operations are saving time, space, and money through palletization and mechanical handling. A growing number of industries have added Materials Handling Departments to their staff, charged with the sole responsibility of speeding the flow of materials in both intra-plant and inter-plant shipments. Many firms now demand that their suppliers ship on pallets as they have found further savings in shipping and receiving in unit loads, eliminating manual handling in and out of freight carriers.

Advantages of Palletization

Manufacturers of all description, storage and warehousing firms, receivers of goods, transportation carriers, and in fact all businesses which during the course of normal operations move goods or materials from one place to another, are assured of many operating advantages and actual dollar savings as a result of adopting a soundly conceived and executed palletization program. Actual case histories of concerns where mechanical handling methods have been adopted repeatedly confirm the validity of the savings readily available to most companies. The 16 advantages of good palletization programs are as follows:

1) By utilizing air space as well as floor space, a palletization program increases the amount of goods storable in any given area.
2) Personnel accidents are reduced by substituting mechanical for manual handling and lifting.
3) Savings in handling costs resulting from palletization range between 25 and 80 per cent, and average from 40 to 45 per cent.
4) Handling time is reduced with a resulting saving in man hours and often elimination of overtime wages.
5) Pallet loading affords ventilation of merchandise in warehouse and during shipments.
6) Palletization simplifies inventorying and to a great extent eliminates inaccuracies in counting and inventory controls.
7) Case histories show adoption of mechanical handling methods and palletized shipments result in almost total elimination of damage of goods.
8) Unitized pallet loads reduce labeling time and expense, since one or two labels per load eliminate the need for marking individual units.
9) Pilferage is reduced when individual items are securely strapped or glue fastened to pallets in unitized bonded loads.
10) Palletization permits uniform placement of stock and results in uncluttered aisles and clean floors.
11) Pallets form a natural "subflooring" to which steel stripping can be easily and securely anchored.
12) Use of pallets often eliminates costly conveyor systems and permits delivery, loading, and unloading at any point accessible to the handling equipment.
13) Pallets fit well into manufacturing phases of goods, thus cutting down production interruptions and bottlenecks.
14) Production workers need not lose valuable time in "lending a hand" in moving materials.
15) By cutting in half loading and unloading time of carriers, and in some cases permitting the loading into one car those items contained in two or three "old method" carloads, palletization: (a) eliminates demurrage charges, (b) in effect greatly increases the utility of carrier equipment, and

Fig. 1.—Palletization has changed warehousing from a square-foot to a cube-foot concept.

[1] Presented at the Fall Meeting of the Northeast Section, FPRS, held Oct. 31–Nov. 1, 1957, in New York, N. Y.

Fig. 2.—Various types of export feright palletized on a New York pier awaiting shipment overseas. Note the versatility of wooden pallets in handling all types and shapes of materials. *Photo courtesy Port of New York Authority.*

(c) increases freight revenues to carriers.

16) Steamship loading time can be reduced with use of pallets, resulting in: (a) faster turnaround of ships, and (b) reduction of costs. Savings are more clearly visualized when it is realized that costs of loading and unloading cargoes are many times greater than those involved in operating a vessel between two ports 1,000 miles apart.

Too few people know the specific technical factors of construction that must be considered and kept in mind in purchasing wooden pallets. Pallets are considered by many to be a class of equipment that everyone takes for granted. Users are prone to attempt to buy them as cheap as possible, repair them only when it is necessary, and throw them away once they have become hopeless wrecks.

Purchasers of materials-handling equipment exercise great care and consideration in making sure that they buy the best possible type of fork-lift and other mechanical equipment. It is customary to assemble all the brains of top management in a firm to select the right fork-lift truck, and then turn over the purchase of pallets to the newest and youngest buyer in the Purchasing Department. If companies would only realize that the several hundred pallets, which they buy for e with *each* fork truck, cost them ore than twice as much as the truck, e cheapest wooden pallet quotation ouldn't be so appealing unless of ourse it was for one of sound nstruction.

Design Requirements

In 1956, more than $125,000,000 was spent for wooden pallets in the United States. The widespread use of pallets has created a need to know more about the proper selection of pallets, and their subsequent proper care during use. In spite of the widespread adoption of pallets, the matter of wooden pallet construction and specifications seems to be the least understood of all technical considerations involved in their use. Many costly mistakes in selecting the right pallet for a given job may be avoided if a user or potential purchaser would but follow a few simple rules. Biggest aid to pallet purchasing is the Minimum Standard Specifications for warehouse pallets published by the National Wooden Pallet Manufacturers Association. These Specifications spell out in detail the various minimum requirements for proper wooden pallet construction. NWPMA has also taken steps to further simplify the purchase of pallets by adopting two pallet grades, namely Grade "A" and Grade "AA", the requirements of which are covered in the Minimum Standard Specifications.

There are many policies that pallet users pursue, which in themselves encourage the purchase of pallets of poor construction and material. These are briefly:

1) Issuing specifications that are lacking in complete detail, and that open up the bidding to manufacturers of inferior quality pallets that have short-use life;
2) Accepting pallets on delivery that do not meet the issued specifications, thus encouraging the pallet supplier to continue such practices in the future;
3) Accepting pallets without brand or stencil identification of the manufacturers, which makes it impossible to determine their source after they have been in use for a year or more; and
4) Improper care of pallets after they are put into use.

It is extremely important that purchasers supply all the necessary technical data required to obtain the desired wooden pallet. Every purchase order or requisition should contain the following information:

1) Size of pallet (length and width; always designate length first).
2) Type of pallet desired.
3) Design of pallet desired.
4) Lumber species permitted.
5) Minimum dimensions of deckboards and stringers or blocks.
6) Moisture content or NWPMA pallet grade.
7) Maximum and minimum individual and total spacing between top and bottom deckboards.
8) Number and position of stringers or blocks.
9) Chamfering, if required.
10) Type, designation, and number of fastenings.
11) Pre-drilling, if required.
12) Wood preservatives, if required.

One cannot impress too much on purchasers the importance of insisting that their pallets be branded or stenciled with the seller's name, or mill designation, or brand. This procedure makes it possible at any time to identify individual pallet performance and the source of supply. The inclusion of the month and year of delivery in such markings is also recommended as good policy.

The importance that all necessary technical data be included in buyer's specifications and purchase orders cannot be stressed too much, because there are some practices followed by a few pallet manufacturers that can condemn pallets to a short use-life. It is important to point out a few of these practices to potential wooden pallet buyers. One of these involves a use of narrow deckboards less than the minimum 3½-inch width prescribed by NWPMA. Such deckboards not only reduce the structural strength of a good pallet, but they also invite early damage.

Another bad practice, which concerns the deck arrangements, is that

Fig. 3.—This is the best way to palletize irregular-shaped articles or items that are subject to damage from compression. Here, bicycles are palletized 5-high on pallets with the use of the Tier-Rack device. It also permits the selection of any item from any pallet without disturbing the load above.

of exceeding the allowed maximum deckboard openings specified by the customer. There is a direct relationship between deckboard openings and the total amount of lumber contained in a pallet. If the maximum allowable openings are exceeded, then a pallet contains less lumber than carried in the customer's specifications. This is important because the amount of lumber determines the cost of the pallet to a large extent.

Many buyers of wooden pallets are very lax with respect to fastening requirements for pallets. Next to the soundness of the lumber, it is the fastenings that play the most important part in wooden pallet construction. It is vitally necessary that a purchaser spell out in detail the requirements of nail fastenings. The NWPMA Minimum Standard Specifications for warehouse pallets furnish an excellent yardstick for nail requirements. Two bad practices exist with respect to nail fastenings for wooden pallets. One involves the pitch or helical angle of the thread of drive-screw nails. If the angle of thread is too small, almost all of the added nail-holding power of drive-screw nails over common nails is lost. Many drive-screw nails used in pallet construction do not offer much increase in holding strength over common smooth-shank nails. Loose deckboards and protruding nails have often been found to be the result of improperly threaded drive-screw nails.

The use of nail fastenings with "chisel" points also invites disaster for the pallet purchaser. Nails with such points do not have as high holding power in wooden pallet construction as do nails with "diamond" points. This is particularly true in the case of pallets made with green lumber. Purchasers often ask, "Why do our pallet suppliers recommend 'Chisel' point nails, if they lack in holding power?" The reason why a few pallet manufacturers use "chisel" point nails is to evade the necessity of pre-drilling deckboards. "Chisel" points diminish the chance of nail splits in wood, but they also damage the wood fibers in driving. The pre-drilling of deckboards is highly recommended, where a manufacturer assembles pallets by hand nailing.

Pre-drilling of deckboards is not required when pallets are assembled by automatic nailing machines, because these machines drive the nails in such a fashion as to prevent the splitting. In hand nailing, the chance of splitting can be satisfactorily lowered by pre-drilling of deckboards without the loss of holding power caused by the use of "chisel" point nails in lieu of "diamond" point nails.

Many pallet users fail to be precise in seemingly small matters such as deckboard widths and openings, and angle of thread and type of points on nails. High maintenance and repair costs of more wooden pallets can be traced to just this lack of preciseness on pallet specifications in most cases.

One way to buy a serviceable wooden pallet for the lowest possible cost would be to specify a NWPMA Grade "A" or Grade "AA" marked pallet. The advantages of these pallets are:

1) The NWPMA Grade Mark pallet offers the buyer a common denominator for measurement of quality;
2) The NWPMA Grade Mark pallet is a uniformly good pallet of sound construction;
3) The NWPMA Grade Mark pallet is ideal for company interchange. You no longer have to negotiate with suppliers or customers about the quality of pallets interchanged when they bear the NWPMA Grade Mark; and
4) The NWPMA Grade Mark pallet is backed by an impartial national trade association dedicated to serving industry with the best in wooden pallets at the lowest possible cost.

Preventive Maintenance Pays Off

Like any other type of materials-handling equipment, wooden pallets give a maximum, trouble-free service life when not abused. If properly designed and constructed to perform under specific conditions, wooden pallets offer more real advantages to users than any other kind.

Although some pallet damage is unavoidable, many pallets are damaged because of carelessness on the part of personnel engaged in pallet handling. Fork truck operators can cause great damage to pallets by pursuing any one of the three following practices:

1) Operators are sometimes careless in entering or withdrawing from pallet openings with tilted forks, which rip off or break the outside edges of end deckboards. This practice can be prevented by placing a level or leveling mark on the mast of all fork-lift trucks. A device known as the "Level-O-Meter" has been scientifically designed for such purposes and is now available from pallet suppliers.
2) Operators cause extensive damage to pallets by striking the stringers or blocks with the forks. Care in entering and withdrawing from pallets can also prevent this hazard.
3) Operators attempt to slue pallets around with one fork in order to line them up for direct two-fork entry. This action can destroy the corner of the pallet and bring on early failure.

Another instance of careless pallet handling is the removal of a top pallet in a pile by simply sliding it off, and allowing it to fall to the ground. This practice can weaken the pallet because it tends to loosen the fastenings, and also causes damage to the deckboards.

Neglect of pallets after they are in use can also be one of the most costly practices encountered in materials handling. Since wooden pallets are economically and readily repairable, a reasonable pallet maintenance program is not complicated and will pay dividends when put into practice.

Such a pallet repair program should stress preventive maintenance as well as correct repair procedures. The following rules should be adhered to:

1) Determine the amount of repair that can be economically done to a damaged pallet. A rule of thumb to follow is to never repair a pallet that requires complete dismantling and reassembly of parts, or when costs of repair exceeds the acquisition cost of a new pallet.
2) Assign one person the responsibility of deciding when to repair and when to replace pallets.

) Use semi-skilled workers for this job, and assign the same crew each time for repair work when needed.

) Provide an adequate working area, proper tools, fastenings, and precut deckboards, blocks or stringers.

) Salvage components of pallets damaged beyond repair whenever possible.

warehouse operations call for sp d where abuse of pallets is unav dable, or where it is undesirable or impossible to discipline careless for truck operators, then the new Pa et Guard device would greatly lo er problems on maintenance costs. Thi metal arrangement, which fits ove the openings of wooden pallets, provides lasting protection for the end deckboards of standard wooden pallets. Where operating conditions call for continuous rough treatment or daily re-use of pallets, the Pallet Guard can provide maintenance-free life for pallets indefinitely.

In February, NWPMA released a new technical pamphlet, which covered the subject of the care and maintenance of wooden pallets. This pamphlet will be helpful to pallet users in setting up maintenance procedures and in obtaining full use from wooden pallets.

It would also be helpful to pallet users to have in their files a copy of another NWPMA publication. This is the NWPMA Technical Handbook on Pallets and Palletization, which contains a wealth of information on this subject, and is the first such Handbook ever written. It is used as a reference book by a number of colleges and universities in the United States and overseas, and about 11,000 copies of this Technical Handbook have been distributed to date. It is available without cost from most reputable pallet suppliers, or may be ordered through NWPMA for $1.00 per copy shipped to United States and Canadian points.

Users of pallets may feel free to write NWPMA at any time for literature, technical advice on specifications and other matters involving wooden pallets. This service is available without obligation by contacting NWPMA, 609 Barr Building, Washington 6, D. C.

Reinforced Plastics as Protective Coatings for Wood[1]

RICHARD MARK and BERT M. ZUCKERMAN

Forest Products Engineer, Balsa Ecuador Lumber Co., New York, N. Y.,
and Consultant in Wood Pathology, Mattapoisett, Mass.

A RAPIDLY INCREASING FIELD of application for reinforced plastics in the last few years has been their use in combination with lumber, plywood, and wood particle boards. This is especially true in the reinforced plastics boat industry, where over 75 per cent of all "glass" boats produced in 1957 contained wood completely imbedded within the reinforced plastic laminate.

Fully imbedded wood, while widely used commercially (primarily to provide stiffness), has been the subject of considerable controversy in both the wood products and reinforced plastics industries.

The central issue in the controversy is whether the encapsulation will promote or prevent decay of the core. Theories that have been advanced to date are basically grouped as follows:

Theory A—The reinforced plastic coating prevents decay under any type of moisture condition, because decay fungi are killed at the time the laminate is applied and are excluded by the coating afterward.

Theory B—The reinforced plastic coating prevents decay only if water does not penetrate the laminate, because it is virtually impossible to eliminate all the fungi within the wood core.

Theory C—The reinforced plastic coating prevents decay regardless of the presence of fungi, because free access to air is halted by the coating, and the normal metabolism of the fungus is prevented.

Theory D—The reinforced plastic coating promotes decay because wood must "breathe" and prevention of this induces "dry rot".

Theory E—The reinforced plastic coating promotes decay because water condensate can built up in the core because reinforced plastics are not vapor barriers.

[1] Presented at the Thirteenth Conference on Reinforced Plastics of the Society of the Plastics Industry at Chicago on Feb. 6, 1958, from which this technical summary was abstracted.

st specimens were prepared by cutting glass mat (lower left), sat- ng it with polyester resin (cup), wrapping this around a balsa bl k, and inserting the assembly in the steel dies shown. After being c d under heat and pressure, the flash (lower right) was removed b grinding.

This 28-foot cabin cruiser is constructed of glued edge-strip planking of cedar and Douglas-fir completely encased in glass-reinforced plastic. Epoxy and polyester resins are used. The smaller outboard motor boats are often built with cores of balsa wood.

After a search of the literature on the subject, plus a study of the longest used commercial application of this combination of materials, the authors decided to institute a comprehensive scientific testing program of these laminates exposed to wood decay fungi.

The phases of the testing program included:

1. Subjecting the following types of blocks to direct exposure to rot fungi under accelerated decay conditions, and then measuring weight loss to determine extent of rotting where it occurred: a. bare balsa wood; b. balsa wood encased in fibrous glass mat and polyester; c. balsa wood encased in fibrous glass mat and polyester that had been drilled to expose the core and resealed (to simulate boat patching, for example); and d. balsa wood coated with polyester alone.

2. Examining test blocks to determine dimensional changes brought about through testing.

3. Isolation to determine the presence or absence of decay fungi in the test blocks.

4. Exposing virile fungal cultures to various ingredients and combinations of ingredients of common polyester and epoxy resin formulations.

Results

In Test 1a, demonstrable effects of the ravages of two common wood-decaying fungi were obtained, and data were obtained for comparison with blocks encased in reinforced plastic exposed to the same conditions and fungi. Test 1b showed that, when subjected to direct exposure to wood-decaying fungi in the presence of moisture and temperature conditions favorable to decay, wood encased in a laminate of glass-reinforced polyester was unaffected due to the protective action of the reinforced plastic skin. Minor weight changes in the sandwich occurred at the same rate when exposed or not exposed to such fungi, other things being equal.

In Test 1c, wood encased by glass-reinforced polyester remained unaffected by exposure to wood-decaying fungi under favorable moisture and temperature conditions, even though the laminates had been damaged so as to expose the wood and then patched with a room-temperature-curing polyester.

In Test 1d, when subjected to direct exposure to wood-decaying fungi in the presence of favorable moisture and temperature conditions, wood sealed with an unbroken coating of polyester resin was unaffected by the fungi. Minor weight changes occurred at the same rate whether the blocks were exposed or not exposed to such fungi, other things being equal. The stresses imposed as a result of testing procedure did not affect the integrity of the resin coating.

Taken singly, the result of Test 2 was an indication, like color change, that wood encased in polyester resin or glass-reinforced polyester was not susceptible to decay when exposed to rot fungi under conditions that rotted the same wood when bare. Taken in conjunction with Test 1, the test was a reaffirmation that a polyester resin coating or a glass-reinforced polyester surface on the wood provided full protection against wood-decaying fungi.

Test 3 offered reaffirmation that, when subject to direct exposure to wood-decaying fungi in the presence of favorable moisture and temperature conditions, wood encased in a laminate of glass-reinforced polyester was unaffected due to the protective action of the reinforced plastic skin, which prevented fungal penetration.

In Test 4, the chemicals tested are all fungitoxic in varying degrees. Most of them are fungistats, several (styrene monomer, 6 per cent cobalt naphthenate cut 1 in 10 with styrene, the organic peroxides and a water-soluble amine curing agent) are fungicides, and at least one (diethylenetriamine) may hydrolyze fungus tissue.

Conclusions

Based on the evidence gathered within the bounds of the experimental design of these tests plus related studies of other agencies, the following conclusions were drawn regarding the various theories. Theory A is apparently correct. Theory B is not substantiated by the evidence. On theory C, information is lacking although the end conclusion would generally be in support of A. Theories D and E are rejected.

Table 1.—EFFECT OF EXPOSURE OF TEST SPECIMENS TO ROT-FUNGI

Grain direction	Pce. No.	Core weight	Glass mat weight	Oven-dry wt. block before test	Weight at start of test (conditioned to over 30% m.c. in core)	Fungus exposure, if any	Test period (days)	Weight at conclusion of test	Oven-dry wt. block after test	Weight loss (IV-IX)	Wt. loss as % of original oven-dry weight
Bare Wood Blocks											
Flat	A11	----	---	2.175	2.780	P. microspora	100	2.220	1.490	0.685	31.5
	A12	----	---	2.020	2.570	P. microspora	100	2.170	1.465	0.555	27.5
	A6	----	---	1.965	2.750	L. Saepiaria	191	3.390	1.925	0.040	2.0
	A7	----	---	2.000	2.760	L. Saepiaria	191	3.295	1.945	0.055	2.8
Wood Blocks Encased in Reinforced Plastic											
Flat	B1	2.4	4.9	12.290	16.280	P. microspora	185	16.295	12.220	0.070	0
	B2	2.3	4.3	10.020	14.010	P. microspora	185	14.005	9.940	0.080	0
	B6	2.3	4.5	10.230	14.155	L. saepiaria	185	14.160	10.150	0.080	0
	B7	2.3	5.5	11.925	16.320	L. saepiaria	185	16.330	11.860	0.065	0
End	B11	2.9	4.1	13.540	17.160	P. microspora	185	17.165	13.480	0.060	0
	B12	2.8	4.3	13.460	18.625	P. microspora	185	18.630	13.390	0.070	0
	B16	2.9	4.5	12.950	17.870	L. saepiaria	185	17.870	12.860	0.090	0
	B17	2.8	4.6	13.470	17.320	L. saepiaria	185	17.325	13.400	0.070	0
Wood Blocks Encased in Reinforced Plastic, then Drilled to Expose the Wood, then Patched with Resin											
Flat	C1	2.05	2.7	9.695	10.320	P. microspora	100	10.485	9.620	0.075	0
	C2	2.82	2.8	9.750	10.650	P. microspora	100	10.890	9.670	0.080	0
	C6	2.05	2.9	9.835	10.750	L. saepiaria	100	10.575	9.765	0.070	0
	C7	2.42	3.0	9.780	10.565	L. saepiaria	100	10.635	9.700	0.080	0
End	C11	2.72	2.6	9.925	10.795	P. microspora	100	10.670	9.850	0.075	0
	C12	2.76	2.9	11.230	12.130	P. microspora	100	11.875	11.165	0.065	0
	C16	2.88	3.6	11.190	12.155	L. saepiaria	100	12.150	11.135	0.055	0
	C17	2.89	3.4	11.200	12.130	L. saepiaria	100	12.290	11.130	0.070	0
Wood Blocks Coated with Polyester Resin											
Flat	D1	2.15	---	6.790	7.495	P. microspora	100	7.520	6.710	0.080	1
	D2	2.02	---	7.650	8.330	P. microspora	100	8.210	7.570	0.080	1
	D6	2.05	---	8.125	8.820	L. saepiaria	100	8.750	8.045	0.080	1
	D7	2.06	---	7.345	8.010	L. saepiaria	100	8.005	7.275	0.070	1
End	D14	2.93	---	9.770	10.720	P. microspora	100	10.475	9.695	0.075	0
	D15	2.78	---	9.895	10.735	P. microspora	100	10.495	9.815	0.080	0
	D16	2.75	---	9.905	10.705	L. saepiaria	100	10.570	9.835	0.070	0
	D17	2.95	---	9.830	10.800	L. saepiaria	100	10.595	9.755	0.075	0

Around the World in Forest Products Research and Development

Thirty-one Countries Send Delegates to FAO Conference

Some 60 delegates from 31 countries attended the Fourth FAO Conference on Wood Technology, April 22 May 2, at tthe Instituto Forestal de Investigacionos y Experiencias at Madrid, Spain, FAO reports.

Mr. P. Martinez–Hermosilla, Director-General of Forests, Spain presided. Elected vice-chairmen were L. J. Markwardt, Ass't Director, U. S. Forest Products Laboratory; J. Campredon, Director, Centro Technique du Bois, Paris, France; and B. Thunell, Director, Wood Technology Dept., Forest Products Research Laboratory, Stockholm, Sweden.

Fifty-one technical papers submitted to the Conference provided background for discussion. Test methods for timber, plywood, fiberboards and particle boards were reviewed and new methods added to the list of recommended test procedures.

The testing of the reaction to fires of building materials was discussed. Most of the participants recommended that more attention be placed on new developments to ensure that test methods are directed towards a realistic appraisal of fire hazards. It was also emphasized that building codes and regulations should adequately reflect the favorable resistance to fire of timbers and treated wood and wood-base materials.

The Conference singled out for action by FAO, work on problems of building materials in housing such as grading systems for wood, better utilization of the inherent strength of structural sizes of wood, and improved methods of effecting wood preservation.

Other Developments Around the World

• Germany

A special issue of *Holz-Forschung* devoted to articles on aspen utilization research has been published by the Institute of Wood Research of the University College of Braunschweig, Germany. Twenty-one articles on the subject appear in the February 1958 issue of the magazine.

Two of the articles are in English, and the others in German have English summaries. Some of the subjects covered in the articles are: cellulose and tension-wood content of poplar wood; investigations on the length of poplar wood fiber; and poplar wood for the manufacture of particle boards. A number of articles deal with the economics of aspen utilization in various countries, and breeding and cultivation of the species.

GERMAN MINISTER MANN tours U. S. forestry operations. Examining an experimental specimen of curved laminated wood at the U. S. Forest Products Laboratory are (l. to r.): Walter Mann, Director, Federal Ministry of Food, Agriculture, and Forestry, Bonn Republic; R. E. McArdle, Chief, U. S. Forest Service; J. A. Hall, Director, U. S. Forest Products Laboratory; Wolfgang Koehler, Forestry Attache, German Embassy, Washington, D. C.; and H. O. Fleischer, Chief, Laboratory's division of timber processing. The German delegation visited the Laboratory this June.

Scanning World Wide Forest Products Publications

Germany

Contributions on Kiln Drying of Wood—First Part: A New Laboratory Kiln for Investigations in a Wide Range of Temperature, Relative Humidity and Air Velocity. [German] Franz Killmann and Adolf Schneider. *Holz,* V. 15, No. 12. Publication of the German Society for Wood Study.

At the Institute for Wood Research and Wood Technics of the University of Munich, fundamental investigations of kiln drying of wood are being made. A series of reports on the results obtained will be published. The first part gives a description of the laboratory kiln and its operating and measuring devices, built for carrying out a program of tests covering several years.

The Sawing Accuracy of Circular Saws and Gang Saws. [German] Gullik Hvamb. *Holz,* V. 15, No. 12. Publication of the German Society for Wood Study.

The variation in thickness marking the work of various kinds of saws was tested with a measuring instrument specifically developed for this purpose. The tests were carried out in 20 saw mills, and all mills employing a certain common type of saw were grouped together. The investigations showed that each saw type requires a precisely determined oversize in thickness in order to yield a cut in accordance with the requested dimensions. These values were determined for all saws tested, and were compiled in tables.

SELECTRIC
sets the pace
in sawyer-operated setworks systems.
FROM 2 TO 30 H.P.
Write for complete information on the system engineered for your production requirements.
• Greater Sawing Accuracy
• Improved Grade Recovery
• Increased Production
• Lower Operating Costs
• Reduced Maintenance Costs
MILL EQUIPMENT INC.
5219 First Ave. South
Seattle 8, Wash.

Abstracts From Current World Literature

Chemical Utilization

Anon. Chemical composition and uses of bark. U. S. Dept. Agr., Forest Serv., Forest Prods. Lab., Rept. No. 1666–5: 10 p. (March, 1957).

Bark represents from 10 to 20% of the weight of dry logs, depending on the wood species. The ash content, solubility, carbohydrate content, and heat of combustion for barks of 24 tree species are presented. The lignin content of barks varies from 14.8 to 49.9% for softwoods and from 25 to 40% for hardwoods. The methoxyl content of unextracted barks is relatively low, varying from 3.9 to 8.9% in softwood and from 7.3 to 15% in hardwood. The proportion of methoxyl groups in the lignin fraction varies from 37 to 89%. The heating value of bark is about the same as that of the wood itself, the average value of softwood barks being higher than that of hardwood barks. Specific components of bark include alkaloids, sterols, esters, glucosides, hydrocarbons, mucilages, tannins, and pigments. Generally, bark is higher in ash, nitrogen, and extractive content than the corresponding wood. The most prominent use of bark is as fuel. Barks can be fractionated into fiber and dust, or into fiber, cork, and powder fractions. Redwood fibers are used for thermal insulation. Douglas-fir fibers as reinforcing fillers. The powders are used as insecticide carriers, glue components, and molding powders; various barks are used as soil conditioners and mulches. The material obtained by alkaline extraction of redwood bark is used as a dispersing agent. Extraction of Douglas-fir bark yields waxes, quercetin, dihydroquercetin, and tannins. Domestic sources of tannins also include the barks of western hemlock and oak. About 40–50% of these tannins are used to control the consistency of oil-well drilling muds. Another bark product is charcoal for recreational uses; the relatively high ash content of bark makes it unsuitable for industrial charcoal. [Bul. Pap. Chem. V. 28, No. 3]

Wood Properties

Kumar, V. B. Swelling studies in wood. Part one. *Norsk Skogind,* 11, no. 7: 259–64, 266–8 (July, 1957). [In English; Norwegian summary]

The influence of water and aliphatic alcohols (methanol through pentanol) on the swelling of some tropical and European woods having densities from 0.15 to 0.70 g./cu. cm. was studied. The wood species included birch (*Betula verrucosa*), beech (*Fagus silvatica*), poplar (*Populus nigra*), pine (*Pinus silvestris*), and umbrella tree (*Musange smithi R. Brown*). Swelling was higher in water-soaked than in alcohol-impregnated specimens of practically all species and was proportional to the ovendry density of all but the lightest species (which swelled more than expected from their density). Fiber-saturation coefficients were computed from density *vs.* swelling data and also estimated by considering the highest liquid content and ovendry density of each species. The estimated values were inversely proportional to the ovendry density, giving a hyperbolic relation. Swelling was also inversely proportional to the molecular weight of the impregnating liquid. Although specimen dimensions affected the swelling behavior, the effect was irregular and inconclusive. [Bul. Pap. Chem. V. 28, No. 2]

Tamolang, Francisco N., Mabesa, Edgardo O., Eusebio, Mario A., Sagrado, Maximo J., and Lomibao, Benigno A. Fiber dimensions of certain Philippine broadleaved woods and bamboos. *Tappi* 40, no. 8: 671–6 (Aug., 1957).

Dimensions of whole fibers from samples of 38 Philippine broadleaved woods and four bamboos determined at the Philippine Forest Products Laboratory are reported. Also included are values derived from these dimensions which others have related to the strength properties of handsheets, usually from soda and sulfate pulps. The average dimensions of the fibers of the woods examined ranged, in mm., as follows: length, from 0.9 to 2.66 (average, 1.20); width, from 0.018 to 0.055 (average, 0.027); thickness of cell wall, from 0.003 to 0.014 (average, 0.0057); and width (diameter) of lumen from 0.005 to 0.032 (average, 0.016). In these respects, these species are about the same as those of other tropical broadleaved woods and European and North American broadleaved pulpwoods. The fibers of katmon (*Dillenia philippiensis* Rolfe) are unusual for this class of wood, having average values for length, width, and cell-wall thickness of 2.66, 0.055, and 0.014 mm., respectively. The average dimensions of the bamboos studied ranged, in mm., as follows: in length, 2.16–3.48; in width, 0.014–0.019; and in width (diameter) of lumen, 0.006–0.007. In these respects, they are typical of bamboos. It is doubtful that the values derived from fiber dimensions which appear related to the papermaking qualities of pulps from broadleaved woods have the same significance with respect to the bamboos. [Bul. Jap. Chem. V. 28, No. 2]

Construction

Building Information. C.S.I.R.O., Graham Rd., Highett, S. 21. Victoria, Australia. published bi-monthly, 32 pp.

This booklet contains abstracts from periodical literature, pamphlets and trade catalogues received by the library of the Division of Building Research in Australia, and as such contains abstracts which are often not available through any U. S. publications. It is categorized by subject matter from A to Z in the Contents, and is a very usable document for those interested in collecting abstracts on particular subjects. [BRI Abstracts, March 1958]

Waste Utilization

Tufts, Don M. Pulpwood chips from sawmill waste. *Tappi* 40, no. 9: 242A (Sept., 1957).

The size of chips made from sawmill waste (debarked slabs, edging strips, and trim ends) can be controlled over a wide range by varying the type of feed, disk speed, discharge, number of chipper knives, and material being chipped. The chips and fibers produced from sawmill waste are essentially the same as those from regular pulpwood, and their utilization should be encouraged. [Bul. Pap. Chem. V. 28. No. 3]

Glues and Gluing

Glue film on a skin glue basis. *Adhasion,* No. 4, July-August 1957, pp. 72, Fritz Hacker & Sohn K.G, Germany.

The firm of Fritz Hacker in Germany has developed a glue film which enables factories without hot presses to use an economic gluing process. The film is cut by scissors, thus saving waste, and is applied by moistening the surface with a sponge and then put under an ordinary press. If there are hot presses available, it is possible to glue within 20 minutes without having to cool. When larger surfaces have to be bonded, the glue film can be used double. [F. D. C. Tech. Bul. V. 7, No. 8]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

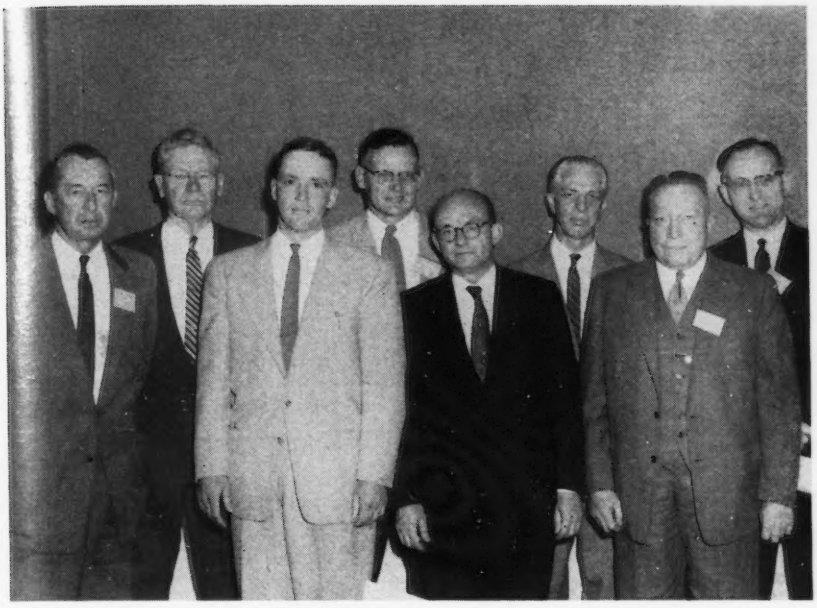
BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

FPRS News-Digest, Continued

New Northern California Officers Elected



New officers were elected at the recent meeting of the Northern California Section, May 1, 2, at Berkeley, Calif. Robert M. Kuhn (second from left, back row), Reese Blow Pipe Mfg. Co., Berkeley, Calif., was elected chairman.

At the meeting (l. to r.) were L. N. Ericksen, Calif. Forest Exp. Sta., new vice-chairman; Victor H. Clausen, Holmes Eureka Lumber Co., secretary–treasurer; B. C. Manson, Simpson Redwood Co.; R. H. Berry, Scott Lumber Co.

Back row (l. to r.) are: A. B. Hood, Ralph L. Smith Lumber Co., trustee; Kuhn; N. T. Shelton, Diamond Match Co., past chairman; and F. H. Kaufert, then president of the Society.

NAMES IN THE NEWS

An honorary doctoral degree was conferred on **Dean Hardy L. Shirley,** State University College of Forestry at Syracuse by the University of Helsinki. The degree, given May 29, was in recognition of the many years of service he has contributed to world forestry as an educator and research scientist. Mr. Shirley is the first American to be so honored by the Finnish institution.

H. L. SHIRLEY

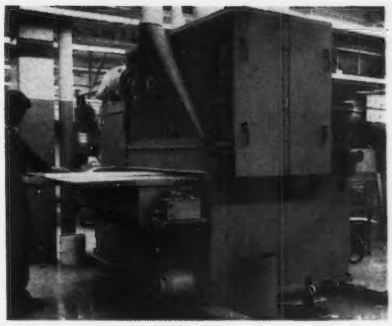
M. H. MATER

Chairman of the 6th Army Research and Development Seminar to be held in Oregon this August is **M. H. Mater,** Mater Machine Works, I... This is the first official Reserve Seminar of its type. Mater is Commanding Officer of the 6518th USAR Research and Development Unit.

Robert W. Erickson, senior in U. of Minnesota School of Forestry, has been named recipient of an NLMA scholarship of $500 in addition to expenses to and from Washington, D. C., for a 10-week period of training at the Timber Engineering Co. laboratory.

Eugene J. Sullivan was appointed executive vice president of the Borden Chemical Co., it was announced recently. Mr. Sullivan, vice president in charge of sales since Jan. 1957, will succeed H. H. Clarke, Jr. He holds a degree in business administration from New York University.

Emanuel Fritz and **E. T. F. Wohlenberg,** nationally known experts in forestry and lumbering, have recently announced the formation of a consulting partnership to be located at Ukiah and Berkeley, Calif. A former general manager and vice president of Masonite, Wohlenberg recently established an industrial forestry course at Yale University. Mr. Fritz has recently been associated with the Redwood Region Logging Conference and is credited as its founder.



Unique in the field is this Yates–American sander, demonstrated at the 3rd National Coated Abrasives Machinery Show, sponsored by Behr–Manning. The automatic sander contains a contact drum plus two abrasive belts for sizing, cutting down, and polishing in a single pass.

Coated Abrasive Machine Show Held at Behr–Manning

The growing importance of coated abrasives as a basic industrial tool was emphasized June 9 through 13 at Troy, N. Y., when 150 new abrasive machines were viewed and tested by several thousand industrial production men from all parts of the United States and half a dozen foreign countries. The week-long show was officially opened with a press preview for industrial editors and a ribbon-cutting ceremony performed by New York's Governor W. Averell Harriman.

The occasion was the 3rd National Coated Abrasive Machinery Show, sponsored by Behr–Manning Co., a division of Norton Company, at its new $1,000,000 Product Engineering building. The abrasive manufacturer acted as host to the machining industry, inviting machine manufacturers to demonstrate developments of the past two years.

Production men from all phases of the metalworking, woodworking, furniture, plastics and other industries brought actual workpieces, and used them to subject the new machines to comparative testing of their grinding and polishing performance.

Features included an 11½-ton woodworking sander which dimensions and finishes in a single pass, a centerless grinder with fully automatic gauging, and a rubber roll grinder able to hold 0.001-in. tolerances on rolls of face widths up to 80 in. Also demonstrated were efficient new dust-collection systems, and a belt storage room held to ideal conditions of temperature and humidity.

WILCO REFUSE BURNER

Three Models. Complete Range of Sizes. Lowest-cost installation. Prefabricated, one-piece panels. Exclusive triple-draft. Sizing engineers available to you.

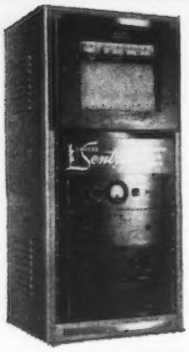
WILCO MACHINE WORKS, INC.
Municipal Airport • Memphis, Tenn.
P. O. Box 3722 • WHitehall 8–4555

3 "Best Buys" in continuous moisture control

LAUCKS Sentry

- CUSTOM
- SPECIAL
- MONITOR

CONTINUOUS MOISTURE DETECTORS



Laucks Sentry Monitor, with Brown Electronik Recorder, $4,200. Other systems from $3,550.

Leading firms recently specifying SENTRY equipment include:

DIAMOND MATCH CO.
DWYER LUMBER CO.
HOLLOW TREE LUMBER CO.
INTERSTATE CONTAINER CORP.
PACIFIC PLYWOOD CO.
ST. PAUL & TACOMA LUMBER CO.
SIMPSON LOGGING CO.
SOUTHERN OREGON PLYWOOD CO.
UMPQUAH PLYWOOD CORP.
U. S. PLYWOOD CORP.
WHITE PINE SASH CO.
WOOD CONVERSION CO.

Recognized by the above firms as the "best buy" in today's equipment market, these latest SENTRY systems for measuring, marking and recording the moisture content of a conveyed material accent a new economy, yet maintain the fine standards of precision control that have long been associated with the Laucks name. Write for detailed information.

LAUCKS LABORATORIES, INC.

1201 Poplar Place — Seattle 44, Washington

— Leaders in Wood Technology for Fifty Years —

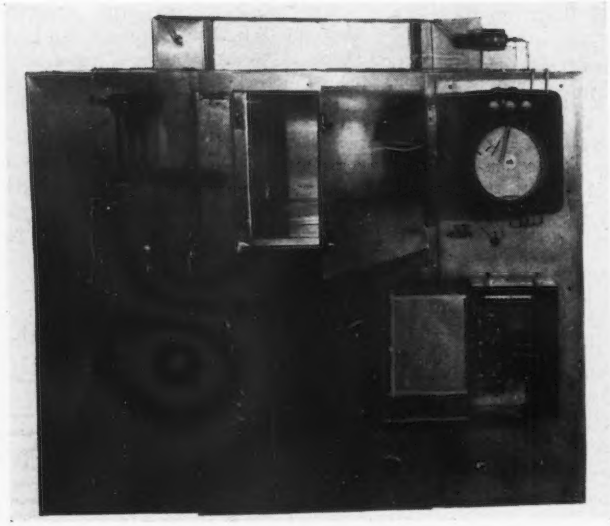
Index to Advertisers

	Page
Behr–Manning Co.	4th cover
Black Brothers Co.	3-A
Buss Machine Works	2nd cover
Laucks Laboratories, Inc.	30-A
Mill Equipment, Inc.	27-A
Reichhold Chemicals, Inc.	2-A
G. Siempelkamp & Co.	3rd cover
The Wel-Dri Co.	30-A
Wilco Machine Works	29-A

DESIGNED FOR THE LABORATORY

- SCHOOLS
- INDUSTRY
- COMMERCIAL

Research



Here is a Laboratory Kiln with All the Features of a Large Commercial Kiln:

- Automatic 2 Pen Recording Controller
- Uniform High Velocity Air Circulation
- Steam Heat—Finned Coils
- Direct Driven Fan—Auto Reversing
- Panel Mounted Electrical System
- Vented & Insulated Aluminum-Clad Cabinet

The **WEL-DRI** *Company*

P. O. Box 2834
730 So. Third St. — Memphis 2, Tenn.

Dependable—Accurate—Durable

Write for More Information Today — *There Is a Wel-Dri Kiln to Fit Your Need*

10 times higher

than the Eiffel-Tower

would be a massive column of

particle boards

on a surface of 11 square feet,

resulting from the

daily output

of the production machines

we now have under construction.

A testimony of confidence of

our customers.

A testimony of the great efficiency

of our company.

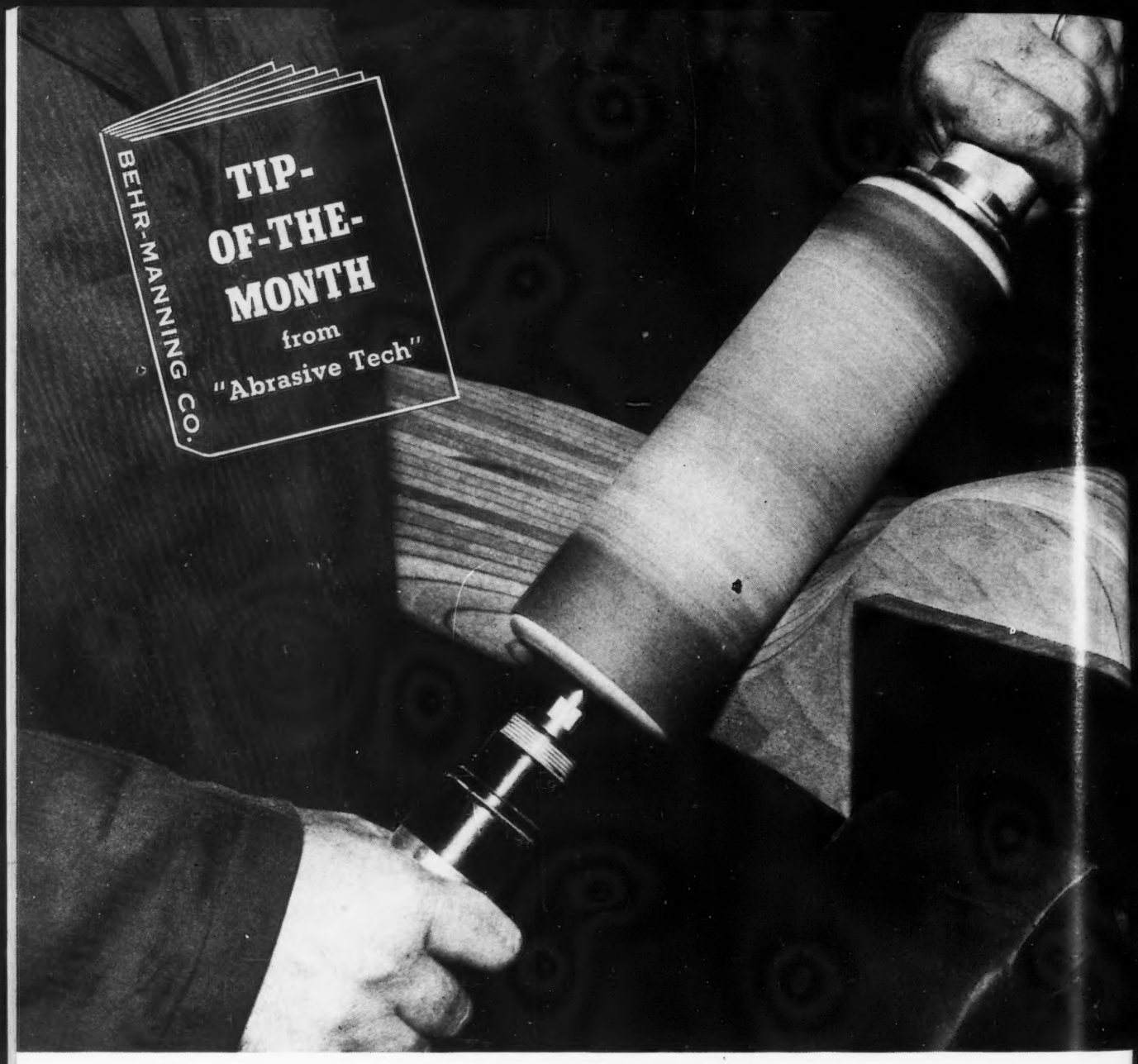
Siempelkamp

G. Siempelkamp & Co.

Maschinenfabrik · Krefeld · Western Germany

Cable: Siempelkampco · Telex No.: 085 3811

Telephone: 28676



Portable Drum Sander Eliminates 6 Sanding Operations

From "Abrasive Tech" comes a continuous flow of new methods, new ways to speed production and reduce costs . . . such as the application of a portable drum sander for finishing laminated airplane propellers to eliminate six previous sanding operations. A Behr-Manning methods engineer can save you time and material . . . just phone your nearest office for a date.

There are 17 "Abrasive Tech" Methods Rooms well-equipped with the latest equipment of all manufacturers (Behr-Manning does not make or sell machines) located at: Atlanta, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Detroit, Grand Rapids, High Point, Indianapolis, Los Angeles, Teterboro, Camden, San Francisco, Seattle, St. Louis, and Brantford, Canada. Main office and plant: Troy, N.Y. For Export: Norton Behr-Manning Overseas Inc., Troy, N.Y., U.S.A.

BEHR-MANNING CO.

TROY, N.Y.

A DIVISION OF NORTON COMPANY NORTON ABRASIVES

BEHR-MANNING®

BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes • NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories